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ANALYSIS OF COMPRESSIBLE FLOW ON HIGH-VELOCITY JET PENETRATION

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 3, Aug 86 pp 20-27

[Article by Lin Xiao [2651 2556] and Wang Jihai [3769 4949 3189]]

[Text] Notations

The subscripts used in this paper have the following meaning: "0" refers to free-stream parameters or parameters upstream of the shockwave; "1" refers to parameters downstream of the shockwave, "w" refers to wall parameters, "t" refers to target parameters, "j" refers to jet parameters, and "n" refers to the number of iterations; two subscripts can also be combined, e.g., "wj" refers to jet parameters along the wall.

A,B,C -- material parameters

c, c_0, c_1, c_{0j}, c_{0t} -- speed of sound

D, D_w, D_n -- boundary velocity

e, e_0, e_1 -- internal energy

f, f_j, f_t, F, F_j, F_t, g -- notations for functions

H -- depth of penetration

k, k_1, k_j, k_t -- exponent of Murnaghan equation of the material

L -- length of jet

q, q_0, q_1 -- flow velocity in a stationary coordinate system

T, γ, γ_0 -- material parameters

V, $\tilde{V}$, $\tilde{\tilde{V}}$ -- jet velocity

λ -- material parameter

1. Introduction

The impact of a high-energy jet stream on a target plate has been a problem of great interest. But up to now, the theoretical treatment of this problem has been limited to the case of incompressible flow; the effect of compressibility has long been ignored. This limitation is primarily due to the mathematical difficulties encountered in treating compressible flow problems

such as the difficulty in deriving an analytical expression for the speed of sound behind the shockwave. However, with the advancement and development in defense technology, the study of this problem has become an important issue.

In 1981, Haugstad and Dullen[1] conducted an analytical study by considering the effects of compressibility of materials and by introducing the shock relation in the stationary impact between a jet and a target. However, in treating the shockwave, they still used the Bernoulli equation without taking into account entropy variations. In Ref. [2], Flis and Chou carried out the study one step further and obtained numerical solutions using several different state equations. But the paper only gave an outline of the general methodology; it did not discuss in detail the various patterns and critical conditions of supersonic and subsonic flows; in particular, they did not give any analystical results, hence it is difficult to use this technique in practical applications.

In this article, we shall discuss in detail various flow patterns through mathematical derivations, and also present a practical analytical method. As in Ref. [1] and Ref. [2], we only consider one-dimensional flow, and we focus on cases governed by the Murnaghan state equation. But the parameters in the equations are assumed to be functions of entropy which must be determined by matching the states behind the shockwave. We also present a brief discussion of some cases which are governed by other state equations.

2. Basic Equations

In the case of constant-velocity jet penetration on a target, the problem can be treated as a stationary one by choosing the origin of the coordinate system at the boundary of the two materials. The boundary can be approximated by a rigid wall where the jet stream and the target flow toward the wall from both sides. Let the flow velocity be q_0 (Figure 2.1). First, consider the case where q_0 is low and shockwave is absent. The irrotational steady-state momentum equation along the streamline is

$$q\,dq + \frac{dp}{\rho} = 0 \tag{2.1}$$

Applying the Murnaghan state equation

$$p = p_0 + \frac{\rho_0 c_0^2}{k}\left[\left(\frac{\rho}{\rho_0}\right)^k - 1\right] \tag{2.2}$$

where k is a constant, we obtain:

$$\int \frac{dp}{\rho} = \frac{c_0^2}{k-1}\left[\frac{p - p_0 + \rho_0 c_0^2/k}{\rho_0 c_0^2/k}\right]^{\frac{k-1}{k}} \tag{2.3}$$

Thus from equation (2.1) one can derive the Bernoulli equation for compressible flow:

$$\frac{1}{2}q^2+\frac{c_0^2}{k-1}\left[\frac{p-p_0+\rho_0 c_0^2/k}{\rho_0 c_0^2/k}\right]^{\frac{k-1}{k}}=\text{const} \tag{2.4}$$

The boundary conditions at the wall are: $q = 0$, $p = p_w$; if we denote the free-stream Mach number by $Ma = q_0/c_0$, then:

$$p_w=p_0+\frac{\rho_0 c_0^2}{k}\left\{\left(1+\frac{k-1}{2}Ma^2\right)^{\frac{k}{k-1}}-1\right\} \tag{2.5}$$

Here p_0 is the pressure far away from the boundary. But if the effect of material strength on penetration is taken into account, then p_0 can be taken as the Hugoniot limit of the material or some other measure of strength.

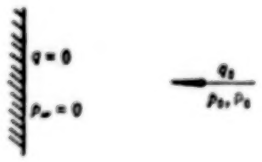

Figure 2.1. Subsonic Flow Pattern

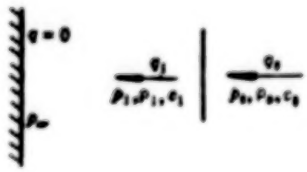

Figure 2.2. Supersonic Flow Pattern

When the flow velocity is very large, a shockwave appears. In the neighborhood of the axis of symmetry, the shockwave can be assumed to be planar; the Hugoniot parameters behind the shockwave are denoted by the subscript 1 (Figure 2.2). Across the shockwave, the laws of conservation of mass, conservation of momentum, and conservation of energy hold:

$$\rho_1 q_0=\rho_0 q_1 \tag{2.6}$$

$$p_0+\rho_0 q_0^2=p_1+\rho_1 q_1^2 \tag{2.7}$$

$$e_0+\frac{p_0}{\rho_0}+\frac{1}{2}q_0^2=e_1+\frac{p_1}{\rho_1}+\frac{1}{2}q_1^2 \tag{2.8}$$

By using the shockwave relation in a condensated medium

$$q_0=c_0+\lambda(q_0-q_1) \tag{2.9}$$

where λ is a constant of the material, one can derive the following:

$$p_1=p_0+\frac{\rho_0 c_0^2}{\lambda}Ma(Ma-1) \tag{2.10}$$

$$q_1=\frac{c_0}{\lambda}[(\lambda-1)Ma+1] \tag{2.11}$$

$$\rho_1=\frac{\lambda\rho_0 Ma}{(\lambda-1)Ma+1} \tag{2.12}$$

$$e_1 = e_0 + \frac{1}{2}(p_1 + p_0)\left(\frac{1}{\rho_0} - \frac{1}{\rho_1}\right) \tag{2.13}$$

In order to determine the speed of sound behind the shockwave, we introduce the Gruneisen coefficient

$$\gamma = \frac{1}{\rho}\left.\frac{\partial p}{\partial e}\right|_{\rho = \text{const}} \tag{2.14}$$

As shown in Figure 2.3, by integrating the above expression with respect to point 1 on the Hugoniot curve and point s on the constant-entropy curve, and letting $\gamma\rho$ = const[3], one obtains:

$$p = p_1 + \gamma\rho(e - e_1) \tag{2.15}$$

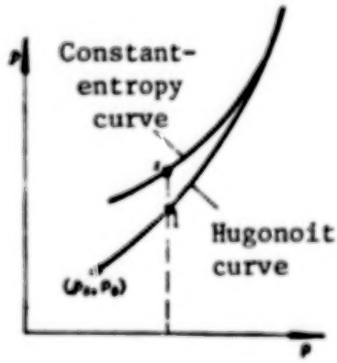

Figure 2.3. Pressure-Density Curve

As $\rho = \rho_1$ varies, (p_1, e_1) vary along the Hugoniot curve and (p, e) vary along the constant-entropy. Thus,

$$\frac{dp}{d\rho} = \frac{dp_1}{d\rho} + \gamma\rho\left(\frac{de}{d\rho} - \frac{de_1}{d\rho}\right) \tag{2.16}$$

From thermodynamics,

$$de = TdS - pd\left(\frac{1}{\rho}\right) = \frac{p}{\rho^2}d\rho \tag{2.17}$$

and from equation (2.13), one obtains:

$$\frac{de_1}{d\rho} = \frac{1}{2}\frac{dp_1}{d\rho}\left(\frac{1}{\rho_0} - \frac{1}{\rho}\right) + \frac{p_1 + p_0}{2\rho^2} \tag{2.18}$$

Substituting the above expression into equation (2.16) gives

$$\frac{dp}{d\rho} = \frac{dp_1}{d\rho}\left[1 - \frac{\gamma\rho}{2}\left(\frac{1}{\rho_1} - \frac{1}{\rho}\right)\right] + \gamma\rho\,\frac{2p - p_1 - p_0}{2\rho^2} \tag{2.19}$$

Let $p \to p_1$, then $e \to e_1$, hence the speed of sound behind the shockwave is obtained as:

$$c_1^2 = \left(\frac{dp}{d\rho}\right)_1 = \frac{dp_1}{d\rho_1}\left[1 - \frac{\gamma\rho}{2}\left(\frac{1}{\rho_0} - \frac{1}{\rho_1}\right)\right] + \frac{\gamma\rho(p_1 - p_0)}{2\rho_1^2} \tag{2.20}$$

For most materials, $\gamma\rho = \Gamma\rho_0$, where Γ is a constant; furthermore,

$$\frac{dp_1}{d\rho_1} = \frac{dp_1}{dMa}\,\frac{dMa}{d\rho_1} = \left(\frac{c_0}{\lambda}\right)^2 (2Ma - 1)[(\lambda - 1)Ma + 1]^2 \tag{2.21}$$

Substituting equations (2.10), (2.11), (2.12), (2.21) into equation (2.20), we obtain:

$$c_1 = \frac{c_0}{\lambda}[(\lambda - 1)Ma + 1]\sqrt{2Ma - 1 - \frac{\Gamma(Ma - 1)^2}{\lambda Ma}} \tag{2.22}$$

This is the analytical expression for the speed of sound c_1 behind the shockwave. In Ref. [3, 4], the calculation of c_1 requires the use of numerical tables. Therefore, derivation of this analytical formula is of significant value in the study of this problem.

In Figure 2.2, one can see that the flow is isentropic from state 1 to the wall, hence one can use the Murnaghan equation which satisfies point 1,

$$p = p_1 + \frac{\rho_1 c_1^2}{k_1}\left[\left(\frac{\rho}{\rho_1}\right)^{k_1} - 1\right] \tag{2.23}$$

and the Bernoulli equation to derive the pressure at the wall:

$$p_w = p_1 + \frac{\rho_1 c_1^2}{k_1}\left\{\left[1 + \frac{k_1 - 1}{2}\left(\frac{q_1}{c_1}\right)^2\right]^{\frac{k_1}{k_1 - 1}} - 1\right\} \tag{2.24}$$

By substituting the post-shock parameters in this equation, we obtain

$$p_w = p_0 + \frac{\rho_0 c_0^2}{\lambda}\left\{Ma(Ma - 1) + \frac{1}{k_1}Ma\left[(\lambda - 1)Ma + 1\right]\left[2Ma - 1 - \frac{\Gamma(Ma - 1)^2}{\lambda Ma}\right]\right.$$
$$\left.\cdot\left[\left(1 + \frac{k_1 - 1}{2\left(2Ma - 1 - \frac{\Gamma(Ma - 1)^2}{\lambda Ma}\right)}\right)^{\frac{k_1}{k_1 - 1}} - 1\right]\right\} \tag{2.25}$$

This is an expression for the wall pressure p_w as a function of the free-stream Mach number, where k_1 is also a function of Ma. There are several approximate methods of treatment: one is to let k_1 be a constant $k_1 = k$; another is to make use of the condition that $p = p_0$ when $\rho = \rho_0$ or $c = c_0$ $p = p_0$, and substitute it into equation (2.23) to derive a transcendental equation for k_1; the third method is to let $c = c_0$ when $\rho = \rho_0$, and derive the following formula from equation (2.23):

$$k_1 = 1 + \frac{2\ln\left(\frac{c_1}{c_0}\right)}{\ln\left(\frac{\rho_1}{\rho_0}\right)} = \frac{\ln\left\{\frac{1}{\lambda}Ma[(\lambda-1)Ma+1]\left[2Ma-1-\frac{\Gamma(Ma-1)^2}{\lambda Ma}\right]\right\}}{\ln\left[\frac{\lambda Ma}{(\lambda-1)Ma+1}\right]} \tag{2.26}$$

When Ma - 1 << 1, we have

$$k_1 = 4\lambda - 1 - (\Gamma - \lambda + 3)(Ma - 1) \tag{2.27}$$

Let Ma → 1, then the value of k from equation (2.2) becomes

$$k = \lim_{Ma \to 1} k_1(Ma) = 4\lambda - 1 \tag{2.28}$$

Finally, since $p_1 > p_0$, one can obtain from equation (2.10) a condition for the existence of shockwave to be:

$$Ma = \frac{q_0}{c_0} > 1 \tag{2.29}$$

Let equation (2.5) be denoted by f(Ma) and equation (2.25) be denoted by F(Ma), then the relationship between wall pressure p_w and free-stream Mach number can be expressed as follows:

$$p_w = \begin{cases} f(Ma) & Ma \leqslant 1 \\ F(Ma) & Ma > 1 \end{cases} \tag{2.30}$$

It is not difficult to show that f(1) = F(1), f'(1) = F'(1), i.e., the relationship between p_w and Ma is represented by a curve shown in Figure 2.4.

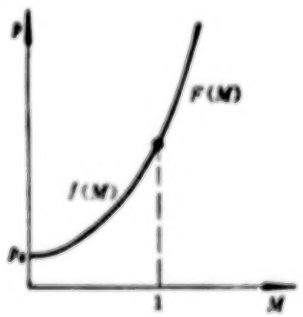

Figure 2.4. Wall Pressure vs Free-Stream Mach Number

3. Flow Analysis and Method of Solution

In a stationary coordinate system, the jet stream approaches with velocity V-D, and the target material approaches with velocity D, as shown in Figure 3.1. At the boundary, the two fluid pressures are equal; thus one can derive the following algebraic equation for the boundary velocity D:

$$\begin{cases} p_{wj} = \begin{cases} f\left(\dfrac{V-D}{c_{wj}}\right) & V-D \leqslant c_{wj} \\ F\left(\dfrac{V-D}{c_{wj}}\right) & V-D > c_{wj} \end{cases} \\ p_{wt} = \begin{cases} f\left(\dfrac{D}{c_{wt}}\right) & D \leqslant c_{wt} \\ F\left(\dfrac{D}{c_{wt}}\right) & D > c_{wt} \end{cases} \\ p_{wj} = p_{wt} \end{cases} \tag{3.1}$$

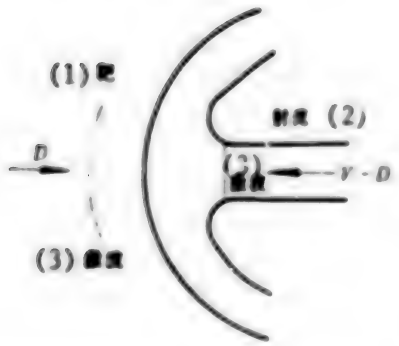

Figure 3.1. Schematic Diagram Showing Jet Penetration

Key:
1. Target
2. Jet stream
3. Shockwave

For a given V, one can determine D from equation (3.1), then the penetration depth H can be determined from the following formula[2]:

$$H = \frac{D}{V-D} L \tag{3.2}$$

where L is the length of the jet. If there is a velocity gradient along the jet, then one can determine the penetration velocity of each infinitesimal jet element dL by using pseudo-stationary approximation, and equation (3.2) can be rewritten as

$$H = \int_0^L \frac{D}{V-D} dL \tag{3.2'}$$

Although p_w is a piece-wise function of D, the physical meaning of a p-D diagram is quite clear. On a p-D diagram, p_{wj} and p_{wt} are continuous curves which intersect at the point (p_w, D_w); this point of intersection is the solution of equation (3.1) (see Figure 3.2).

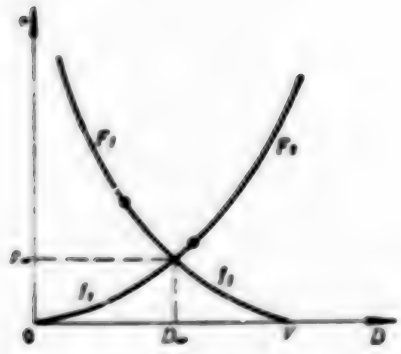

Figure 3.2. Determination of Penetration Velocity by Graphic Solution

Clearly, when V is small, no shockwave will be generated in either material, and the point of intersection falls on two subsonic curves, D_w is given by the following formula:

$$f_j\left(\frac{V-D}{c_{0j}}\right)=f_t\left(\frac{D}{c_{0t}}\right) \tag{3.3}$$

If V is very small, equation (3.3) can be expanded in a Taylor's series about the point zero to yield

$$V=\left(1+\sqrt{\frac{\rho_{0t}}{\rho_{0j}}}\right)D+\frac{\rho_{0t}}{8}\sqrt{\frac{\rho_{0t}}{\rho_{0j}}}\left[\frac{1}{(\rho_0 c_0^2\beta_1)_j}-\frac{1}{(\rho_0 c_0^2)_t}\right]D^3 \tag{3.4}$$

This shows that at the origin, the variation of V with respect to D is in agreement to 2nd order with the result of incompressible flow theory; the effect of compressibility on the penetration depth is determined by $\rho_0 c_0^2$ of the two materials.

When V increases, a shockwave will first appear in one of the materials. If we call the state corresponding to Ma = 1 the critical state, then it can be seen from Figure 3.2 that shockwave will first appear in the material which has a lower wall pressure under critical state, $\bar{p}_w$ (called critical pressure). From equation (2.5), the critical pressure of a material is given by:

$$\bar{p}_w=p_1+\frac{\rho_1 c_1^2}{k}\left[\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}}-1\right] \tag{3.5}$$

As pointed out earlier, p_0 contains a factor of material strength, and $\rho_0 c_0^2$ is a measure of the dynamic state of the material; hence $\bar{p}_w$ gives a composite measure of the compressibility of the material.

Assume $\bar{p}_{wj} > \bar{p}_{wt}$ (same argument applies for the opposite case), then a shockwave will first appear in the target material. At the critical point, $D = c_{0t}$, then the critical jet velocity can be obtained from equation (3.3) as:

$$\tilde{V}=c_{wt}-c_{oj}\sqrt{\frac{2}{k_j-1}\left[\frac{\tilde{p}_{wt}-p_{oj}-\left(\frac{\rho_0 c_0^2}{k}\right)_t}{\left(\frac{\rho_0 c_0^2}{k}\right)_j}\right]^{-\frac{k_j-1}{k_j}}-1} \tag{3.6}$$

When V the boundary velocity D_w will be the root of the following algebraic equation.

$$f_j\left(\frac{V-D}{c_{oj}}\right)=F_t\left(\frac{D}{c_{wt}}\right) \tag{3.7}$$

If V continues to increase, then one can see from the p-D diagram that shock-waves will appear simultaneously in the jet stream and the target material. Let the jet velocity at the critical point be $\tilde{V}$, then $\tilde{V} - D = c_{0j}$ or $D = \tilde{V} - c_{0j}$; substituting this into equation (3.7) yields V. When $V > \tilde{V}$, the boundary velocity D_w will be given by the following equation:

$$F_j\left(\frac{V-D}{c_{oj}}\right)=F_t\left(\frac{D}{c_{wt}}\right) \tag{3.8}$$

The above analysis procedure greatly facilitates the solution of the impact problem of compressible flow. For a given free-stream velocity V, one can assume an array of boundary velocities $\{D_n\}$, where D_0 can be chosen as the theoretical solution from incompressible flow, and D_n is determined recursively from the solution D_{n-1}. The procedure is continued until the quantity $|p_{wj} - p_{wt}|$ calculated from equation (3.1) is less than ε, and the resulting D_n is the required solution. Once D is determined, other solutions can be readily obtained.

As an example, we calculated the interaction of a copper jet with a steel target and an organic glass target. The material parameters are:

copper: $\rho_0 = 8.93$ Mg/m^3, $c_0 = 3.92$ km/s, $\lambda = 1.488$, $\Gamma = 1.96$

steel: $\rho_0 = 7.84$ Mg/m^3, $c_0 = 3.596$ km/s, $\lambda = 1.686$, $\Gamma = 1.69$

organic glass: $\rho_0 = 1.186$ Mg/m^3, $c_0 = 2.745$ km/s, $\lambda = 1.451$, $\Gamma = 0.8$

The p_0 for all the materials are chosen to be zero. In Figure 3.3, we plotted the ratio of penetration depths H calculated from compressible and incompressible flow theories as a function of velocity. These results are in good agreement with those of Ref. [2].

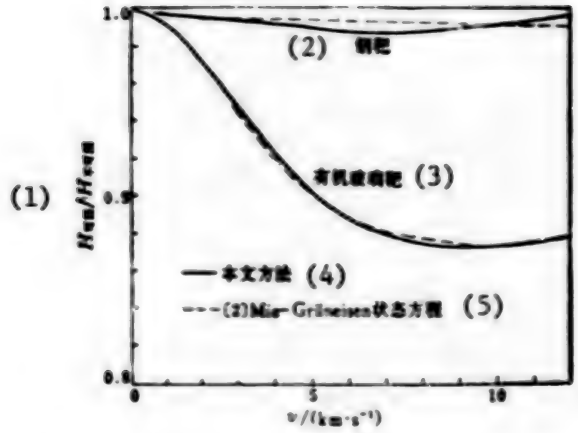

Figure 3.3. Effect of Compressibility on Penetration

Key:

1. $H_{compressible}/H_{incompressible}$
2. Steel target
3. Organic glass target
4. Method given in this paper
5. Mie-Gruneisen state equation

4. Discussion

In this paper, an analytical procedure for studying the interaction of a compressible jet with a target using p-D curves is presented. This method greatly facilitates the analysis of subsonic and supersonic flows, and gives a clear picture of the problem. By matching the Hugoniot parameters with the Murnaghan state equation, not only the entropy variation caused by the shockwave is taken into account, but the solution is simplified. In particular, the derivation of an analytical expression between the wall pressure p_w and free-stream Mach number Ma provides a convenient formula in actual application. The calculated results are shown to be in good agreement with those calculated using other state equations.

Although the discussion here is limited to the Murnaghan state equation, many results of this paper can be extended to the case of other state equations. For example, consider the Mie-Gruneisen equation

$$\begin{aligned} p &= (A\mu + B\mu^2 + C\mu^3)\left(1 - \frac{\Gamma\rho_0\mu}{2\rho}\right) + \Gamma\rho_0 e \\ &\equiv g(\rho) + \Gamma\rho_0 e \end{aligned} \tag{4.1}$$

where

$$\mu = \frac{\rho}{\rho_0} - 1$$

The thermodynamic relation (2.17)

$$\frac{de}{d\rho} = \frac{g(\rho)}{\rho^2} + \frac{T\rho_0}{\rho^2} e \tag{4.2}$$

can be integrated to get

$$e = e_0 \exp(-T\mu) + \exp\left(-\frac{T\rho_0}{\rho}\right)\int_{\rho_0}^{\rho} \frac{g(\rho)}{\rho^2}\exp\left(\frac{T\rho_0}{\rho}\right)d\rho \qquad (4.3)$$

from which one can write the Bernoulli equation:

$$\frac{1}{2}q^2 + \frac{p}{\rho} + e(\rho) = \text{const} \qquad (4.4)$$

From this equation, one can readily analyze the relationship between the free-stream q and the wall pressure; the same analytical procedure can be applied to the patterns of subsonic and supersonic flows. Of course, one can see from equations (4.3) and (4.1) that $\frac{p}{\rho} + e(\rho)$ is an implicit function of p, which makes the solution more difficult.

As shown in Figure 3.3, when the jet velocity V increases, the calculated results based on the Murnaghan state equation begins to rise toward unity. Whether this result reflects reality remains to be verified by experiments. We also found that in the case of a copper jet penetrating an organic glass target, the effect of compressibility is very pronounced. Therefore, in a penetration process involving two materials with totally different mechanical properties, the effect of compressibility must be taken into consideration.

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COMBINED CALCULATION OF DEFORMATION AND STRESS FOR THE BODY AND SABOT OF AN APFSDS

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 3, Aug 86 pp 28-34

[Article by Qian Mingang [6929 3046 0474]]

[Text] 1. Introduction

The calculation of stress and deformation of the body and sabot of a high-velocity armor piercing fin-stabilized discarding sabot (APFSDS) at the instant of launch is an important part of the strength design process. The structure of a typical APFSDS in shown in Figure 1.1. The body and sabot are connected by 28 teeth, and the sabot is divided into three sections. At the time of launch, the chamber pressure ratio is quite high, hence the simplified method of calculation can no longer satisfy design requirements. In 1981, Zhu Haosong and Duo Xinliang published an article "Finite Element Analysis of the Launch Stress of an APFSDS" (it will be referred to as "Analysis" in this article) where they successfully calculated the launch stress of an APFSDS using a finite-element program, but they did not present the results of stress for the body or the interaction between the body and the sabot. Also, the method of coupling between the body and the sabot given in that article can be further improved.

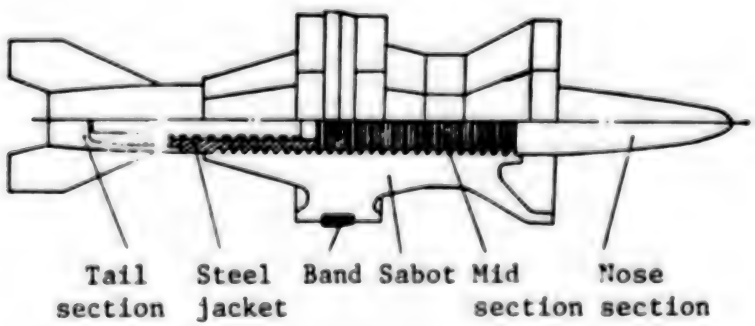

Figure 1.1. An Armor Piercing Fin-Stabilized Discarding Sabot (APFSDS)

In this paper, the substructure capability of the general ASKA program (see Ref. [1]) is used to carry out combined calculation of stress and deformation for the body and sabot of an APFSDS. Specifically, by treating the radial and axial degrees of freedom of the coupled nodes on the contact surface of the body and sabot separately, improved results are obtained. The paper not only generates the deformation pattern and the equal-stress lines of the body and sabot under high chamber pressure, but also gives the load distribution curves between the body and the sabot. These results provide useful data for improving the product design.

2. Construction of a Mechanical Model

In order to construct a mechanical model for an APFSDS at launch, the following assumptions are made:

(1) The body and sabot are treated as an integral structure with axial symmetry.

Figure 2.1 shows the cross section of an APFSDS. In Figure 2.1(a), the body and the base pressure p_d are axially symmetric, and the sabot is divided into three sections. Strictly speaking, the stress and displacement on the sabot are periodic-symmetric. But since the three sabot sections are only subject to compression, and the structure and load are symmetric with respect to the three boundaries, the circumferential displacements on the three boundaries A-A, B-B, C-C must be zero. Similarly, on each section of the sabot (see Figure 2.1(b)), since the sabot structure, the base pressure p_d, the reaction force p_F, and the condition of zero displacement on the boundaries A-A, B-B are all symmetric with respect to the center cross section D-D, the circumferential displacement on the cross section D-D must also be zero. By the same token, the circumferential displacements on all radial cross sections of the sabot are zero; thus, the axially symmetric model satisfies the displacement boundary conditions of the sabot.

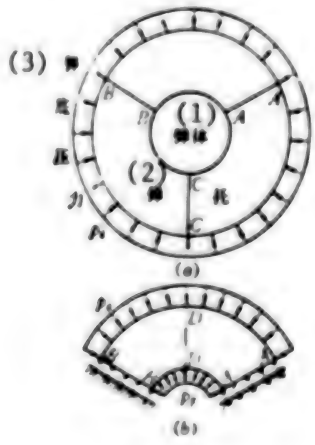

Figure 2.1 Cross Section of an APFSDS

Key:
1. Body
2. Sabot
3. Base pressure

The boundaries of the three sabot sections are under tension, and the stress boundary condition is: normal stress $\sigma_\theta \leq 0$. Since the base pressure due to external load on the entire structure p_d is less than 0, it follows from Ref. [2] that this condition is also satisfied.

The above analysis shows that the boundary conditions at the boundaries of the sabot are consistent with the calculation procedure which treats the body and sabot as an integral structure with axial symmetry.

(2) The body and sabot are modelled as two substructures, and the radial and axial degrees of freedom of the coupled nodes on the contact surface are treated separately.

In the finite-element calculations of the APFSDS, the distribution of forces between the body and sabot along the 28 connecting teeth is unknown. Therefore, in order to provide a good representation of the contact between the body and sabot, we use the general ASKA program, and the body and sabot are modelled as two independent substructures. In considering the actual contact conditions of these two substructures, only the nodes on the load-bearing surfaces of the 28 connecting teeth and the front and rear positioning surfaces are coupled; the other nodes are not. Furthermore, the nodes on the load-bearing surfaces are coupled only in the axial direction, not in the radial direction (i.e., the axial displacements of the body and sabot at these nodes must be the same, but the radial displacements can be different); the nodes on the positioning surfaces are coupled only in the radial direction, not in the axial direction (i.e., the radial displacements of the body and sabot at these nodes must be the same, but the axial displacements can be different).

It should be pointed out that the method presented here is different from that given in the article "Analysis." In the article "Analysis," the body and sabot have common nodes and boundary lines on the load-bearing surfaces; no distinction is made between the axial and radial degrees of freedom. The results of calculation also show that there are significant differences between our method and the method given in the article "Analysis." Therefore, to provide a close approximation of the actual conditions, it is essential to treat the two degrees of freedom of the nodes separately.

(3) In the body substructure, the core and the steel jacket are considered to be tightly joined together, i.e., they have common nodes at the boundary without being further divided into two substructures.

(4) The pressure exerted by the band on the sabot is assumed to be the same as the base pressure inside the chamber.

(5) The effect of the nose and tail on the mid section is represented by an equivalent uniform pressure distribution.

(6) The weight of the body and sabot and the effect of aerodynamic drag are neglected.

3. Selection of Element and Grid Pattern

The finite-element grid patterns of the above mechanical model are shown in Figure 3.1 as Grid 1, Grid 2 and Grid 3. Grid 1 represents the body and Grid 2 represents the sabot. The shaded elements of Grid 1 represent the steel jacket.

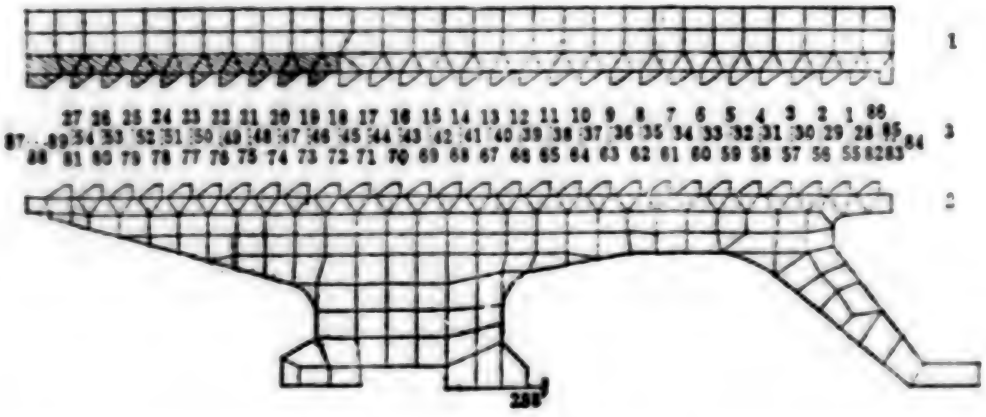

Figure 3.1. Finite Element Grid Patterns of the Body and Sabot

To achieve higher accuracy, we primarily use 8-node elements which are right-quadrilateral and axially-symmetric (QUAX8); we also use 6-node elements which are triangular and axially-symmetric as transitional elements (TRIAX6). In transitional regions with round corners, we use a small number of elements with curved boundaries (QUAXC8 and TRIAXC6). The number of elements and the number of nodes in Grid 1, Grid 2 and Grid 3 (primary grids) are listed in Table 3.1.

Table 3.1. The Number of Elements and the Number of Nodes in Grid 1, Grid 2 and Grid 3

Grid number	Total number of nodes	Total number of elements	Number of elements	Number of elements	Number of elements	Number of elements
1	552	143	116		27	
2	704	189	153	1	32	3
3	89					
Total	1345	332	269	1	59	3

In Grid 3, there are 89 condensation points. Points 83, 84, 88, 89 represent the radial positioning surface, where only the radial degree of freedom is maintained (i.e., the body and sabot have common radial displacements at these nodes, but they are allowed to slide in the axial direction); the remaining points represent the axial load-bearing surface where only the axial degree of freedom is maintained (i.e., the body and sabot have common axial displacements at these nodes, and they are allowed to slide in the radial direction). The point 82 is on both the radial positioning surface

and the axial load-bearing surface, hence it is necessary to maintain both radial and axial degrees of freedom.

In order to eliminate the rigid displacement of the structure, an axial constraint is added to the No 288 node to avoid singularity in the rigidity matrix.

4. Load Calculation

Figure 4.1 shows the position and direction of various loads on the body and sabot of an APFSDS. Specifically:

(1) The maximum base pressure p_d is perpendicular to the surface of the structure; its value can be obtained from tests and other sources.

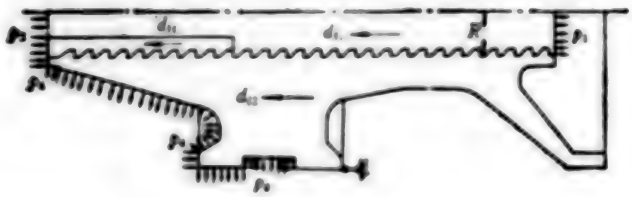

Figure 4.1. Loads on the Body and Sabot

(2) Inertial forces:

The inertial force in a unit volume of the steel jacket is denoted by d_{f0}, the inertial force in a unit volume of the core is denoted by d_{f1}, and the inertial force in a unit volume of the sabot is denoted by d_{f2}. Then, $d_{f0} = nd_0$, $d_{f1} = nd_1$, $d_{f2} = nd_2$, where d_0, d_1, d_2 are respectively the densities of the alloy steel jacket, the tungsten alloy core, and the aluminum alloy sabot, n is the overload coefficient

$$n = \frac{\frac{\pi}{4} D^2 p_d}{q}$$

where D is the diameter of the sabot, and q is the mass of the projectile.

(3) The compression exerted on the mid section by the nose section is

$$p_1 = \frac{nq_1}{\pi R^2}$$

where q_1 is the mass of the nose section that has been cut off, R is the radius of the body.

(4) The tension exerted on the mid section by the tail section is

$$p_2 = \frac{nq_2}{\pi R^2} - p_d$$

where q_2 is the mass of the tail section that has been cut off.

5. Calculated Results of Stress and Deformation

By using the above mechanical model, the grid patterns, the load and boundary conditions, the stress and deformation of a certain APFSDS under maximum chamber pressure are calculated. Figure 5.1 shows a computer-generated deformation pattern of the body and sabot. Figure 5.2 shows the distribution of equal-stress lines of the body and sabot.

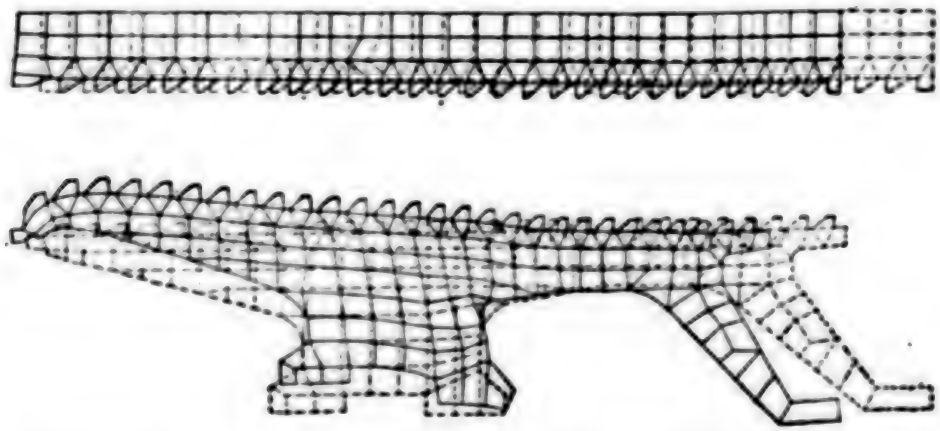

Figure 5.1. Deformation Pattern of the Body and Sabot

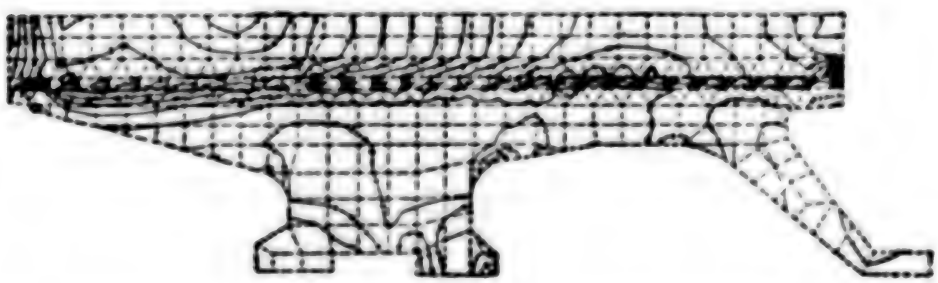

Figure 5.2. Distribution of the Equal-Stress Lines of Equivalent Stresses in the Body and Sabot

In Figure 5.1, the dashed lines indicate the grid pattern of the original structure, the solid lines indicate the grid pattern of the deformed structure. The plotted displacements of the deformed structure are magnified 50 times. In fact, the maximum axial displacement is -0.454 mm, and the maximum radial displacement is -0.215 mm. We see that the radial displacement is smaller than the gap between the body and the sabot in the radial direction, as expected. Also, the maximum radial displacement of the forward section of the sabot is 0.0558 mm, which is within the manufacturing tolerance of the sabot and the chamber. This indicates that the boundary conditions used in this paper are appropriate.

In Figure 5.2, the grid patterns of the body and sabot are represented by the dashed lines, and the equal-stress lines are represented by solid lines with

numerical labels. Each number n represents n x 10 kg/mm^2. Figure 5.2 clearly shows the stress level and distribution of the body and sabot. For example, the high-stress region on the sabot is located at the last 8-10 teeth of the 28 connecting teeth; the stress levels at other locations, except for a few spots of stress concentration, are generally quite low. On the other hand, the high-stress region of the body is located in the vicinity of the root section of the forward 6-10 connecting teeth; there is also evidence of stress concentration at the contact points of the first and last tooth. At other locations of the body, the equivalent stresses are relatively small. From the results of actual target shooting, the last 8th and 9th teeth show traces of plastic deformation. This is consistent with our calculated results. The stress distribution plots provide valuable information for improving the product design. For example, the mass of the sabot can be reduced by reducing the dimensions of the section where the stress level is relatively low; on the other hand, the dimensions of the section with high stress level can be increased to improve the overall design.

In establishing the axially-symmetric mechanical model, it was pointed out that the normal stress on the boundary of the three-section sabot should satisfy the condition $\sigma_\theta \leq 0$. Now we can see from stress calculations that this condition is basically satisfied. At the vertices of the 258 elements of the sabot, 220 elements have circumferential stresses $\sigma_\theta < 0$, which is more than 85 percent of the total; at the other 38 vertices, while the circumferential stresses are positive, they are very small, and primarily distributed at the front end of the sabot. Since the front end is a low-stress region which is of little interest in stress analysis, we feel that from the overall point of view, the assumption of an axially-symmetric mechanical model is a reasonable one.

In order to understand the interaction between the body and the sabot, and to provide a reference for future design calculations, Figure 5.3 shows that distribution of the interaction force p between the 28 connecting teeth along the z-axis. The dashed line in Figure 5.3 is plotted from calculated values of the nodal reaction per unit arc on the 28 connecting teeth; the solid line is a 4th order polynomial fitted to the above data using the method of least squares. We see that the distribution of forces on the connecting teeth varies considerably. Therefore, it is clearly inappropriate to use a simple approximation for this distribution; it is essential to carry out the calculations using the method of substructure.

6. Concluding Remarks

In this paper, combined calculation of the stress and deformation of a certain high-velocity APFSDS at launch is carried out by using an axially-symmetric mechanical model and the substructure capability of the general program ASKA and its elastic segment ASKAI. This approach is closer to reality than the model used in the article "Analysis"; it can be used to calculate the launch stress and deformation of the body and sabot for a wide variety of high-velocity APFSDS.

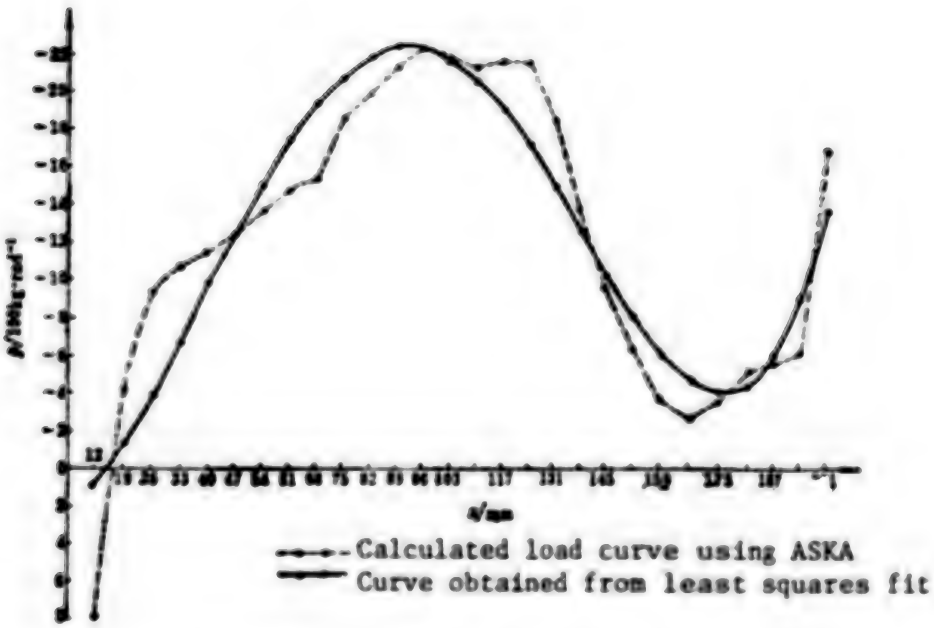

Figure 5.3. Load Distribution Curves Between the Body and the Sabot

In the above analysis, we did not address the question of whether the elements and nodes will enter the plastic state because the launch of an armor-piercing projectile is a high-velocity, high-pressure, and high strain-rate process. Tests show that when the strain rate is less than 10^{-3}/s, the material properties are basically stable and can be represented by the results of static tests; when the strain rate is high, the material properties will exhibit drastic changes with significant increases in the flow limit and strength limit (see Ref. [3]). Since the strain rate of an APFSDS is several orders of magnitude higher than 10^{-3}/s, it is not sufficient to have only the static properties when carrying out the elasto-plastic analysis of the body and the sabot. However, at the present time we do not have stress-strain data on materials under high-speed load, hence we can only carry out a general analysis of the stress level and distribution, we cannot determine whether or not a certain point is in a plastic state. In fact, because of the mechanical properties of materials under high strain rate, when the stress at a certain point exceeds the yield limit, the stresses at the neighboring points will be redistributed, and the maximum stress value will be lower than that calculated by the elastic program.

Acknowledgement

Acknowledgement is due to Zhu Ronggui, Zhu Naili, Chang Liangming, and Zhang Xueyi for valuable discussions with the author during this study.

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CSO: 4008/75

NEW PHYSICAL EXPLANATION OF PHASE-CONJUGATE WAVES PRODUCED IN BACKWARD STIMULATED SCATTERING

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13, No 10, 20 Oct 86 pp 618-622

[Article by He Guangsheng [6378 0342 3932], Liu Dun [0491 4163], and Liu Songhao [0491 7313 6275] of the Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences; manuscript received 9 July 1985]

[Text] Abstract: This paper gives a new physical explanation of the process whereby backward stimulation scattering (BSS) produces phase-conjugate (PC) waves. We believe that what happens in the process of backward stimulated scattering is that there are two nonlinear processes simultaneously present: a pure stimulated scattering process and a partial degeneration four-wave mixing-frequency phase-complex conjugate process. The tight coupling of these two processes makes the BSS wave possess, to a certain degree, the features of a phase conjugate to the incident wave. We solved the nonlinear coupled-wave equations for the backward SBS and proved that it has perfect PC properties only when some particular conditions are satisfied. Experimentally a detection method for four-wave mixing-frequency was adopted and confirmed the theoretical results.

I. Introduction

Previously, theories on the properties of backward stimulated scattering phase complex conjugates have commonly held that the phase complex conjugate was produced in the gain process of stimulated scattering. Consequently the mathematics of the theoretical problem began in a set of gain equations for stimulated scattering like those below [1]:

$$\left.\begin{aligned}\frac{\partial \varepsilon_1}{\partial z}-\frac{i}{2k_1}\Delta_\perp \varepsilon_1=0\\ \frac{\partial \varepsilon_2}{\partial z}+\frac{i}{2k_2}\Delta_\perp \varepsilon_2=\frac{1}{2}g|\varepsilon_1|^2\varepsilon_2\end{aligned}\right\} \tag{1}$$

Because the mathematical solution of equation (1) is very difficult, there is no way but to adopt excessively artificial assumptions and an approximate treatment in the mathematics. Consequently this leads to different authors

giving different results. [1-3] Even more incomprehensible is that the selection of a stimulated gain model leads to forward stimulated scattering, similarly possessing the ability to reconstruct the spatial information of the incident light. [4] This inference does not agree with experimental facts.

Clearly there is a need for further discussion on the essence of backward stimulated scattering production of phase conjugate waves. In the second section of this paper we will attempt to give a new physical explanation for this process. In the third section, with backward SBS as an example, we will do theoretical analysis, and in the fourth section we will briefly describe the decisive experiments done using four-wave mixing-frequency methods.

II. Pictorial Explanation of the Physical Mechanism

Up to now people have been in the habit of seeing the use of the four-wave mixing-frequency method to produce phase conjugate waves and the production of phase conjugate waves by backward stimulated scattering as two completely different processes to be discussed separately and have not considered the possibility that there is an essential link between the two. With the aid of the principles of holography and reconstruction first proposed by Gabor [5], we believe that the production of phase conjugate waves by the backward stimulated scattering method can, in essence, be summed up as a kind of process of phase conjugate waves produced by four-wave mixed-frequency. Or, in other words, PC waves from BSS are a kind of reconstruction process from an induction holographic grating occurring in a scattering medium.

In general, experiments to produce phase conjugate waves from backward stimulated scattering are usually a single laser beam after passing through a translucent aberration plate incident on the scattering medium. According to Gabor's principle, the incident laser beam which passed through the aberration plate can be thought of as made up of two components, one which is an undisturbed plane wave and the other, a diffracted or disturbed wave which contains the spatial information of the aberration plane. The intersecting portions of the two part incident light fields in the scattering medium produce interference and, through induction of refractivity, change forming an induced holographic grating. Considering that the aberration image drawn into the aberration plate is not large, the disturbed wave makes up only a small part of the incident wave. Consequently there is reason to believe that only when there is an undisturbed incident wave portion can it first reach or exceed the threshold of stimulated scattering and produce backward stimulated scattering. The backward stimulated scattering produced also ought to possess a more ideal wave front. In the transmission process of passing through the scattering medium in the opposite direction, on the one hand it continually undergoes the gain action of stimulated scattering while, on the other hand, it acts as a scanning light beam when passing through the holographic grating zone, producing a reconstruction of the disturbed wave with which it increases in intensity. Our analysis will show under certain conditions that after the true backward stimulated scattering wave and the reconstructed wave produced by its passing through the induced holographic grating zone are superimposed together and emerge from the scattering medium they will become, to a certain degree, a phase conjugate

of the total incident light beam. The process described above is fundamentally a quasi-collinear four-wave mixing-frequency process. The total incident wave contains two parts with average frequency ω_0 and in the backward scattered wave there are also two parts which have an average frequency of ω_S. For stimulated Brillouin scattering and stimulated Rayleigh scattering, ω_0 and ω_S differ very little. Consequently, basically it can be approximately regarded as being entirely degenerative four-wave mixing-frequencies. For stimulated Raman scattering, the value of $\omega_0-\omega_S$ is larger and it is a situation of partial degenerative four-wave mixing-frequencies. At this time there ought to appear larger holographic reconstruction aberration. This tallies with known experimental facts.

III. Theoretical Analysis

According to the above discussion, the incident wave is represented as the sum of two parts, that is

$$E_l = (e_{l1} + e_{l2}e^{i\theta_l})e^{i(\omega t + kz)} \tag{2}$$

in which we hypothesize the wave as propagating in the -z direction and $e_{\ell 1}$, $e_{\ell 2}$ respectively are the real amplitudes of the plane wave and the disturbed wave containing the spatial information assumed to be constants. θ_ℓ is the phase correction factor of the aberration wave front with respect to the ideal plane wave front and is a function of (x, y, z). Similarly the backward SBS is also composed of two parts written as:

$$E_s = (e_{s1}(z) + e_{s2}(z)e^{-i\theta_s})e^{i(\omega t - kz)} \tag{3}$$

in which e_{s1} is the real amplitude of the true backward stimulated scattering wave, e_{s2} is the real amplitude of the reconstructed wave, and θ_s is the phase difference between the actual wave front and the plane wave front. Here we assume that $e_{\ell 1}$, $e_{\ell 2}$, θ_ℓ, θ_s, e_{s1}, e_{s2} all are not functions of time. That is, in the subsequent discussion we deal only with the steady state situation.

Ignoring the attenuation of the E_ℓ wave in the mutual action process, the equation it satisfies is:

$$\nabla^2 E_l - \frac{n^2}{c^2}\frac{\partial^2 E_l}{\partial t^2} = 0 \tag{4}$$

Substituting (2) into the above formula it is not difficult to get:

$$\partial\theta_l/\partial z + \frac{1}{2k}(\nabla\theta_l)^2 = 0 \tag{5}$$

$$\nabla^2\theta_l = 0 \tag{6}$$

The equation that the true backward SBS satisfies is:

$$\partial^2 E_{s1}/\partial z - \frac{n^2}{c^2}\frac{\partial^2 E_{s1}}{\partial t^2} = \mu_0\frac{\partial^2 P^{(NL)}}{\partial t^2} \tag{7}$$

in which $E_{s1} = e_{s1}(z)e^{i(\omega t - kz)}$, $P_{s1}^{(NL)}$ are describing the nonlinear degree of polarization of the stimulated scattering gain. Under steady state conditions, $P_{s1}^{(NL)}$ is [3]

$$P_{s1}^{(NL)} = i\epsilon_0 \chi e_{l1}^2 e_{s1} e^{i(\omega t - k_s z)} \tag{8}$$

Here the polarization coefficient $i\chi$ is the value under conjugate conditions and is a pure imaginary number so χ is a pure real number. In the following discussion we assume $k_s \approx k$. With formula (8) substituted into formula (7), under the slowly changing amplitude approximation we get the equation satisfied by e_{s1} and solution obtained by solving this problem:

$$\partial e_{s1}/\partial z = -\frac{k}{2}\chi |e_{l1}|^2 e_{s1} = -\frac{g}{2}|e_{l1}|^2 e_{s1} \tag{9}$$

$$e_{s1}(z) = e_{s10} e^{\frac{1}{2}g|e_{l1}|^2 z} \tag{10}$$

e_{s1} displays the exponential propagation law which is familiar to us while e_{s10} is a constant of integration.

In what follows we discuss the four-wave mixing-frequency process. At this time it is the mutual action of the aberration wave, the pumped wave, and the backward SBS wave produced by the pumped wave. According to the theory of four-wave mixing-frequency, the three-step nonlinear polarization strength of the contribution to the reconstruction of the aberration wave produced by the mutual action in the medium of these three waves is:

$$P_{s2}^{(NL)} = i\epsilon\chi e_{l1} e_{l2} e_{s1} e^{-i\theta_s} e^{i(\omega t - kz)} \tag{11}$$

Here we consider the nonlinear polarization coefficients of the two processes to be the same. This is reasonable since these processes take place in the same matter which leads to the micro physical mechanism of nonlinear polarization being the same so it is not hard to get the equation satisfied by e_{s2} and θ_s:

$$\partial e_{s2}/\partial z + \frac{e_s}{2k}\nabla^2\theta_s = -\frac{k\chi}{2} e_{l1} e_{l2} e_{s1} \cos\theta \tag{12}$$

$$\partial\theta_s/\partial z + \frac{1}{2k}(\nabla\theta_s)^2 = -\frac{k\chi}{2} e_{l1} e_{l2} e_{s1}/e_{s2} \sin\theta \tag{13}$$

in which $\theta = \theta_l - \theta_s$. We can get the solution of the two equations above for conditions of small aberration and slow amplitude change at which time we can consider:

$$\left|\frac{1}{e_{s2}}\frac{\partial e_{s2}}{\partial z}\right| \gg \left|\frac{1}{2k}\nabla^2\theta_s\right| \tag{14}$$

$$|\partial\theta/\partial z| \gg \left|\frac{1}{2k}[(\nabla\theta_l)^2 - (\nabla\theta_s)^2]\right| \tag{15}$$

With these two approximations, the two formulae (12) and (13) simplify to

$$\partial e_{s2}/\partial z = -\frac{g}{2} e_{l1} e_{l2} e_{s1} \cos\theta \tag{16}$$

$$\partial\theta/\partial z = -\frac{g}{2} e_{l1} e_{l2} e_{s1}/e_{l2} \sin\theta \tag{17}$$

Putting formula (10) into the above it is not difficult to get the solutions of these two equations:

$$e_{s2} = \frac{e_{l2}}{e_{l1}} e_{s10} e^{\frac{1}{2} g |e_{l1}|^2 z} \tag{18}$$

$$\sin\theta = \sin\theta_0 e^{-\frac{1}{2} g |e_{l1}|^2 z} \tag{19}$$

Summing up formulae (10), (18), and (19), when $\theta = 0$, the form of representation of the total backward SBS field is

$$e_s = A' e^{\frac{g}{2}|e_{l1}|^2 z} [e_{l1} + e_{l2} e^{-i\phi_0}] \tag{20}$$

This solution is composed of two components. One part is the e exponential gain term we knew about. The other part is the phase conjugate wave of the incident wave amplitude. From formula (19) we know that there is a relationship between θ's tendency to zero and the product of the three parameters. Stretching the gain length, or increasing the light intensity, or selecting a medium with a higher gain coefficient facilitate obtaining the phase conjugate wave of the incident wave through backward SBS. In addition, the value of θ_0 has an effect on the tendency of θ to zero. From formula (19) we know that the larger the aberration of the aberrant wave, the more difficult it is to get its phase conjugate wave.

IV. Experimental Research

The experimental light path is shown in Figure 1. The arrangement of this light path received inspiration from the experimental apparatus of Basov, et al. [6]. Therefore through inspection of the phase conjugate degree of the backward wave we can inspect the phase conjugate degree of the backward SBS. Figure 1 shows that in the experiment we used one reflection lens R_4. The angle θ between the two beams changed by passing through it makes the dysphotic laser incident at different regions in the medium where the backward SBS process occurs. Consequently its backward wave also reflects the phase conjugate degree of the backward SBS for different regions, i.e., follows the conditions of gain length change.

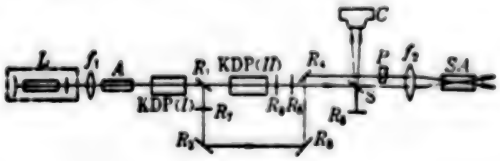

Figure 1. Simplified Diagram of the Experimental Apparatus Light Path

In the experiment we used a YAG modulated Q laser composed of a plano-convex cavity plate. Passing through the first KDP crystal we got a laser with $6.7 \times 10^{+5}$ W and wave length of 0.53 μm. In the light path we carried out experiments under the two conditions of placing and not placing an aberration plate in the light path with the idea of explaining the effect of aberration on phase conjugates. Passing through KDP(II) we also obtained the second laser beam of 0.53 μm wave length with a power of 1×10^5 W which could be attenuated via an echelon attenuation plane R_5 to control it so that it could not produce self backward SBS when incident alone. The high-light and dysphotic light passed through a lens f_2 to converge on the sample box (SA). The sample was CS_2 in a sample box 14 cm long. S is a sharp wedge glass sampling plate. We used a camera (C) to photograph a record of the dysphotic incident light selected passing through S and the near field image of its backward light beam. P was an aberration plate.

With changes of the intersection angle θ, the coordinates of the intersection point of the two beams in the medium are

$$\left.\begin{array}{ll} \text{horizontal} & x_0 = \dfrac{2h - l\theta}{2h} f \\ \text{vertical} & y_0 = -\dfrac{1}{2} l\theta \end{array}\right\} \tag{21}$$

Above we take the lens as the vertical coordinate with the optical axis as the horizontal coordinate. The parameters in the formula are defined as follows: h is the distance from the laser spot center to the optical axis when the two beams travel parallel to the optical axis. In the experiment this was taken as 0.75 cm. ℓ is the distance traveled, when parallel to the optical axis, of the high-light laser emerging from R_4 to lens f_2 (31 cm). f is the focal length of lens f_2 (50 cm). θ is the adjustable inclination angle. When the high-light laser and optical axis are parallel it is zero. When the high-light beam approaches the optical axis θ is larger than zero and when it diverges θ is less than zero.

Figure 2 is a set of photographs recorded at different inclination angles θ in the experiment. The light spot to the right in each photograph is the near field image of the incident dysphotic beam while the spot to the right is the light intensity distribution near field of its corresponding backward wave. Each figure separately corresponds to different stimulated scattering regions. Table 1 gives the intersection point computed according to formula (21) of the positions corresponding to the two beams represented in each photograph.

From Figu[illegible] 2 we can get the following information:

1) Before the aberration plate is in place, doing a comparison of the light intensity distribution of the backward wave and the light intensity distribution of incident dysphotic laser (here we actually compare the near field distribution outlines of the two beams). It can be seen that when the gain length is shorter, like shown in Figure 2(a) and (b), there are no similar

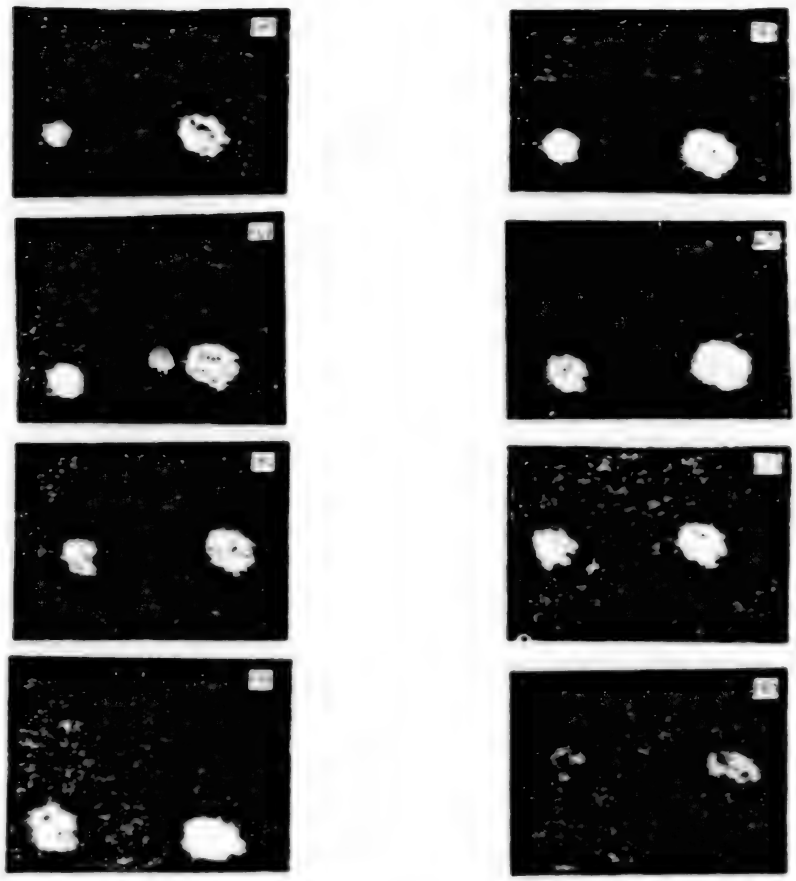

Figure 2. Near Field Distribution Photographs of Incident Light (right side spot) and Backward Reconstructed Wave (left side spot) in Four-Wave Mixing-Frequency Identification. Experiment shown in Figure 1.

Table 1. Intersection Point in the Medium of the Two Laser Beams

Fig. 2	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
θ(mrad)	−0.706	0	0.706	1.65	2.65	3.96	1.65	2.65
x_0(cm)	50.7	50	49.3	48.3	47.3	45.9	48.3	47.3
y_0(cm)	0.011	0	−0.011	−0.026	−0.041	−0.063	−0.02	−0.041

places. As the gain length is increased, the detail of the dysphotic gets reconstructed step by step in the backward wave and the light intensity distribution of the backward wave comes more and more to resemble that of the incident dysphotic beam as shown in Figure 2(e) and (f). Figure 2(c) and (d) illustrate the transitions process of reconstruction. This result proves that the process of phase conjugate for backward SBS is gradually perfected with the increase of gain length.

2) After placing the aberration plates, we only detected two spot positions which corresponded to conditions where the backward wave had already rather well reconstructed the spatial information of the dysphotic beam without the aberration plate. These results at this time indicate that the features of the phase conjugate of the backward wave are not ideal as shown in Figure 2(g) and (h). This illustrates that when the aberration is larger the phase conjugate features of the backward SBS are inferior.

The above two experimental results are in agreement with our theoretical conclusions.

From this experiment we realized that this method could be used to study the process of backward stimulated scattering and provide the functional relationship of backward stimulated scattering gain with incident light intensity and gain length thereby obtaining microscopic information about stimulated scattering medium.

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12966/6091
CSO: 4008/13

A 10 W TRANSVERSE FLOW EXCIMER LASER

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13, No 10, 20 Oct 86 pp 635-638, 645

[Article by Lou Qihong [2869 4388 3163], Zheng Chengen [6774 2110 1869], Jiang Miao [3068 8693], Jiang Yueqing [1203 7048 3237], Ding Zean [0002 3419 1344], Ding Aizhen [0002 1947 5271], Dong Jingxing [5516 2529 2502], Wei Yunrong [7614 6663 2837], Qi Jianping [4359 1696 1627], and Wang Runwen [3769 3387 2429] of the Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences; manuscript received 8 August 1985]

[Text] Abstract: This paper reports on an ultraviolet (308 nm) excimer laser with output power of 10 W. Features of the gas circulating system and the X-ray pre-ionization dosage distribution are given. The effect of gas flow velocity on the laser output is also discussed.

In some applications, there are occasions when an excimer laser with a larger pulsed energy (on the order of jules), an average power of a few Watts, is needed. This paper reports on an ultraviolet (308 nm) excimer laser with maximum output of 10 W.

I. Gas Circulation System

Figure 1 gives a simplified structural diagram of the gas circulation system. The centrifugal fan is driven by a 2 kW motor with a high-pressure rotating sealed system between the motor and the fan. The system is made of stainless steel to prevent corrosion by the halogen gas and down stream from the laser discharge zone there is a tube-plate type, water-cooled, heat exchanger. In order to prevent the influence of vibrations on the entire system (mainly the laser discharge zone) when the centrifugal fan is running, the input and output of the centrifugal fan are connected to the system with stainless steel corrugated pipe.

For gas flow quantity control at the laser chamber we adopted a nozzle design to reduce the boundary layer. The anode uses the Zhang electrode shape and is embedded in a glass-steel plate. The cathode is a plane style electrode, the backside of which is the source for X-ray pre-ions. The separation between the two electrodes is 2.5 cm.

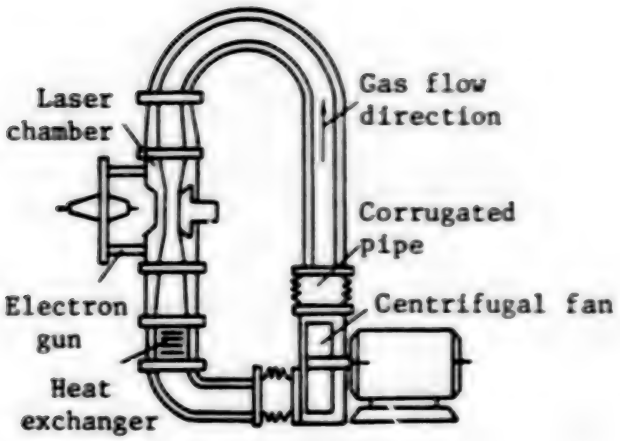

Figure 1. Diagram of Transverse Excimer Laser Gas Circulation System Flow

The entire gas circulation system is made of stainless steel. Flow velocity in the discharge zone [was measured at over] 20 m/s. Figure 2 gives the flow velocity distribution along the optical axis in the 70 cm long laser discharge zone. In the figure, the flow field distribution for direct current meter driving potentials of 100 V and 150 V are given separately. Experimental results show that the flow field is symmetrical about the center of the discharge zone along the optical axis so Figure 2 only gives one-half of the flow field distribution.

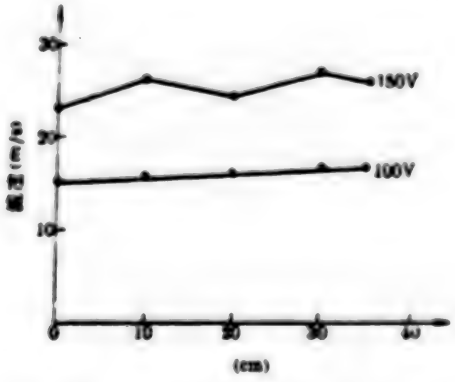

Figure 2. Distribution of the Flow Velocity Along the Optical Axis in the Laser Discharge Zone. The voltages indicate the driving potential of the centrifugal fan's DC motor.

From Figure 2 we see that although there are undulations in the flow velocity when the potential of the DC motor is 150 V, computations show that for the 150 V versus 100 V situation, the average value of $\frac{\Delta V}{V}$ is around 0.13. However, for 100 V the flow distribution is even flatter. These conclusions indicate that the gas circulation system has a fine flow field distribution.

II. The X-Ray Pre-Ion Source and Its Dose Distribution

At the backside of the laser discharge cathode is a cold cathode X-ray source.[4] The 0.6 cm wide by 60 cm long cathode of the cold cathode electron gun is mounted on a cover with about 1.5 cm between it and the electron gun cathode. The cathode is made of tantalum foil at the back of which there is an 0.15 cm thick aluminum plate. The thickness of the tantalum foil was chosen suitably to prevent electron penetration but have good permeability with respect to X-rays. In order to make the X-ray pre-ion source able to operate under repeating frequencies, the fine heat conduction ability of the tantalum is helpful for diffusion conduction of heat. A three-stage Marx generator provided a 100 kV, 500 ns wide pulse. The X-ray intensity of each pulse in the laser discharge zone was measured to be about 5 mRem.

In order to control the radiation range of the X-rays, behind the laser discharge cathode there was a masking plate with a hole 1 cm X 60 cm to pass X-rays. Figure 3 gives the geometrical structure of the X-ray's distribution in space. The oblique line part represents X-rays passing through the hole. The cylinder represented by dashed lines is the laser oscillation harmonic cavity zone while the X, Y, and Z axes stand for the directions of the X-ray dose distribution in the three coordinate directions we measured.

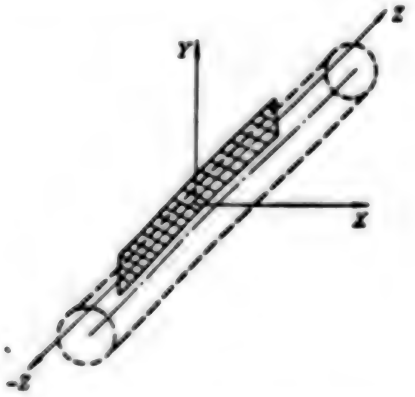

Figure 3. Coordinate System for Measuring the X-Ray Dose Distribution in the Laser Discharge Zone

We used a model FJ-301G_2 radiation dose meter produced by Beijing Nuclear Instruments to measure the X-ray dose distribution in the three coordinate directions. Figure 4 gives the distribution along the Z axis which averaged about ±25 percent. This is already sufficiently homogeneous for large volume excimer avalanche homogeneous discharge. Figure 5 gives the distribution of the X-ray dose along the X and Y axes. In the Y direction, within a range of 10 cm the dose reduction is less than 25 percent while in the X direction it is reduced 3 ~ 4 times as much. But in the design of our laser, the electrode separation is only 2.5 cm and within this range the X-ray dose reduction is also less than 25 percent. Summarizing the above, in the range of the laser discharge zone, the X-ray dose variation is less than ±25 percent, providing the necessary conditions for large volume homogeneous discharge.

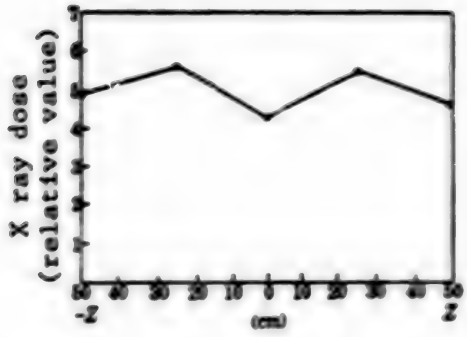

Figure 4. X-Ray Dose Distribution Along the Z Axis

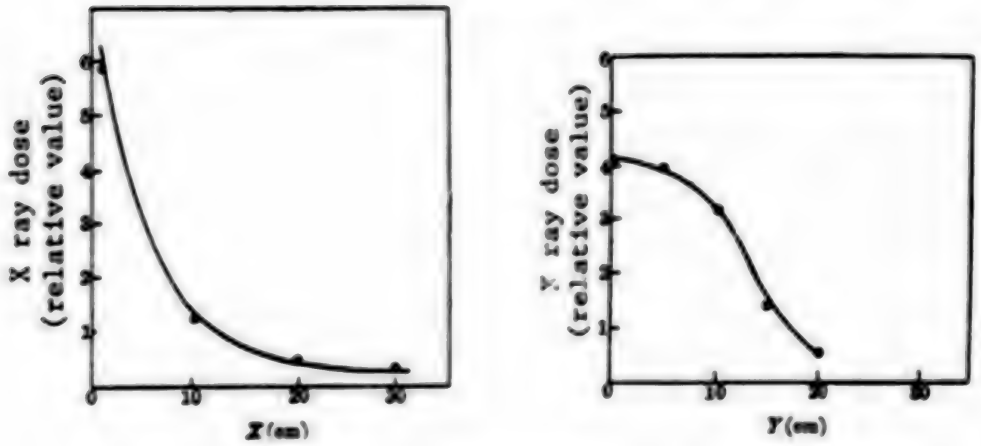

Figure 5. X-Ray Dose Distribution Along the X and Y Axes

III. Experimental Results From the Laser

The laser discharge power source uses a two stage Marx generator with a capacitance of 0.066 μF to do pulsed charging of a low inductance ceramic capacitor block (C = 0.054 μF) and is passed through a channel switch with respect to the laser discharge. Figure 6 gives the variation in laser output under different voltages. From the figure we see that the output power is greatest with a potential of 80 - 100 V and when the potential V = 150 V, the laser output falls off slightly. These results and those given in Figure 2 are in agreement because when V = 100 V the flow distribution is more even than when V = 150 V.

Based on the measured values of flow velocity, when the potential increases from 60 V to 150 V, the flow velocity rises from 15 m/s to 25 m/s. We feel that the laser is able to operate normally with the flow velocity in the range from 15 - 25 m/s. In the experiments described below we generally maintained a flow velocity of 20 m/s.

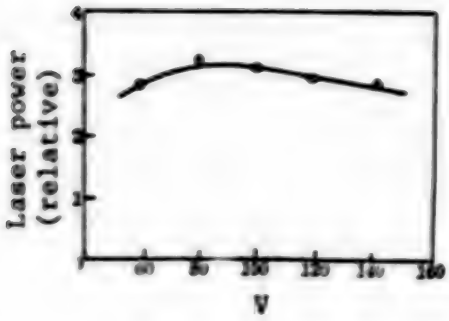

Figure 6. Effect of Centrifugal Fan Motor Potential (Gas Velocity) on Laser Power

One of the authors[5] has done research on thermal effects with regard to steady state repeating frequency excimer laser discharge. According to the discharge gas thermal expansion model produced by their article, when the repeating frequency reaches 10 times per second, the thermal effects make the output power drop to about half that of the value expected without considering thermal effects. Under the conditions of transverse flow of the present article, the thermal effects are overcome by the gas circulation system. The solid line in Figure 7 gives the relationship between laser output power and the repetition frequency. From the figure we see that the laser output power increases linearly with the repetition frequency. For comparison the broken line in the figure gives the output characteristics under steady state conditions. Under conditions of 10 times each second, with HCl:Xe:Ne = 1:6:857, and total gas pressure of 3.9 atm, the maximum output power is 10 W.

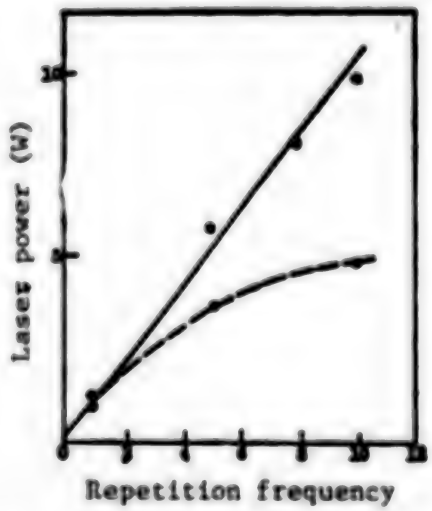

Figure 7. Relation of Repetition Frequency and Laser Output Power

Figure 8 shows the effect of the Ne gas pressure on the laser output power. When we maintained HCl = 3.5 Torr and Xe = 30 Torr while changing the pressure of Ne, the output power went up with increasing Ne pressure. The two lines in the figure correspond separately to the discharge potentials:

64 kV and 54 kV. Under these two conditions the maximum efficiency of the apparatus was about 0.9 percent.

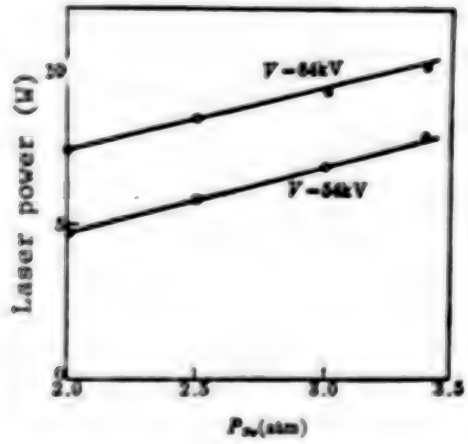

Figure 8. Effect of Ne Gas Pressure on Laser Output Power

From Figure 8 we see that the efficiency of the apparatus increases with increasing Neon pressure. To find the effect of Xenon component pressure we maintained the HCl concentration at 3.5 Torr and the Neon pressure at 2 atm, making the Xenon pressure vary from 10 Torr to 30 Torr which increased the laser output power linearly. Figure 9 shows the effect of Xenon gas pressure on laser output power. Of note is that since the volume of the entire apparatus is large (over 200 l^3) and the price of Xenon is rather steep, optimization of the gas components has not been further perfected.

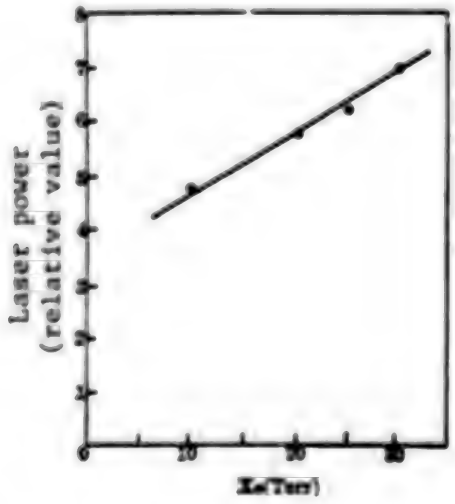

Figure 9. Effect of Ne Gas Pressure on Laser Output Power

IV. Discussion

1. As the repetition frequency increased, the synchronization between the laser discharge and the X-ray pre-ionization clearly became steadily more important. We used an OK-19 oscilloscope simultaneously to detect the flutter period between two different repetition frequencies. The experiment results shows that when it was 5 times per second, the flutter period was 50 - 60 ns, and when it was 8 times per second the flutter interval was 90 - 100 ns. Further increasing the repetition frequency to 10 times per second the flutter interval was 120 - 130 ns. According to our previous analysis of the dynamics of discharge pumped XeCl laser X-ray pre-ionization, under lower concentrations of HCl

$$[HCl] < 0.15\%$$

we selected a suitable delay interval, such as 0.8 μs. When the delay interval changes from 500 ns to 1200 ns (flutter interval of 700 ns), the variation in laser output energy is less than ±5 percent. Under repeating frequency operation, with changes in the repetition frequency the energy variation of a single pulse is ±10 percent, slightly larger than the variation value for the steady state case. The reason for this is possibly related to shock wave effects produced by laser discharge. For this reason, under the conditions of our experiments, the above-mentioned flutter intervals do not influence the output characteristics of the laser. Of course, in order to increase further the repetition frequency, in improving the circuit design, it would be beneficial to reduce the flutter interval.

2. Under transverse flow conditions we measured the directionality of the laser beam finding that with steady state average pulse conditions, it was basically uniform at about 4 mrad.

3. Using a photoelectric detector and a high speed oscilloscope we photographed the 308 nm laser wave form. With 5 - 10 pulses per second, 10 or more pulses completely overlapped on the oscilloscop photographs with half height widths of 85 ns. The above results show that this apparatus, run under repeated frequencies, outputs rather stable signal amplitudes.

In the apparatus design, we received assistance from our colleagues of this institute, Hong Kui and Shen Junquan, to whom we express our gratitude here.

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SATURABLE ABSORBERS FOR COLLIDING PULSE-LOCKED Nd:YAG LASERS

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13, No 10, 20 Oct 86 pp 664-665

[Article by Lin Xing [2651 2502], Zhang Wenzhen [1728 2429 3791], Wu Fengtie [0702 6646 6993], Zhuang Huiming [8369 6540 7686], and Zheng Yunshan [6774 0061 1472] of Huaqiao University Physics Department and Sun Zhanao [1327 0594 7663] of the Chinese Academy of Science, Shanghai Institute of Optics and Fine Mechanics; manuscript received 3 August 1985]

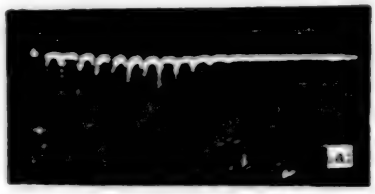
[Text] Abstract: In this paper, the mode-locking of pentamethylidyne dissolved in various solvents was studied and their average pulse duration measured. The mode-locked pulse trains using pentamethylidyne, and BDN as the saturable absorbers were observed on a 500 MHz oscilloscope respectively, and their mode-locking quality and stability were compared.

In passive mode-locked lasers, the mode-locking phenomena of dyes such as pentamethylidyne and unidecamethylidyne in different solvents has been reported but to date there have been no notices of this in collider pulse mode-locked lasers. However, study of the saturable dye features in collider pulse mode-locking is very important in regard to the performance of laser systems. This article discusses and studies only the small signal translucivity and other parameters with respect to pentamethylidyne, unidecamethylidyne, BDN dye, solvents, and solutions used in CPM. The cavity we used was an anti-resonance ring CPM cavity with a radius of curvature of 3 m in its front mirror. The mirror used for the collider pulse was a 22.5°, 1.06 μm totally reflecting medium film. The total cavity length was 1705 mm. The dye box was put at the center boundary of the circuit and placed at an angle to ensure that the dissipation would be small, there would be no sub-cavity, and the dye solution put in the dye box would not move.

I. Saturable Absorbent Pentamethylidyne

We used pentamethylidyne dyes and compared their mode-locking situations in ethylene chloride, nitrobenzene, nitrobenzene and ethylene chloride (1:1), and chloroform. In the experiments a 500 MHz oscilloscope was used to observe their mode-locked pulse sequences. Using a two photon fluorescence method to measure their average mode-locked pulse width the results were as follows:

1. For the CPM pulse sequence of pentamethylidyne in different solvents see the image shown on the oscilloscope (500 MHz, 100 mV/grid, 20 ns/grid) in Figure 1. From the figure we see that the mode-locking pulse sequence total width for pentamethylidyne in the different solvents is basically the same (average 110 ~ 120 ns).



a) 1,2-ethylene chloride

b) Nitrobenzene and ethylene chloride (1:1)

c) Nitrobenzene

d) Chloroform

Figure 1. Images of Mode-Locking Sequences of Pentamethylidyne in Different Solvents

2. The average mode-locked pulse widths measured for pentamethylidyne in the various solvents when the translucivities were close are given in Table 1. The average pulse widths were measured with a SMJ-2 model two photon fluorescence meter. From the table we see that the average pulse width of ethylene chloride was most narrow (11 ps) while the average pulse width of the chloroform solvent was the biggest (19 ps).

Table 1. CPM Pulses of Pentamethylidyne in Different Solvents

Solvent	Translucivity (1.06 μm) T_0 (%)	Average pulse width (ps)
Ethylene chloride	53.4	11
Nitrobenzene	54	16
Nitrobenzene and ethylene chloride	49.8	16
Chloroform	51.7	19

3. The CPM pulse sequence stability order of pentamethylidyne in different solvents was: ethylene chloride (pure laser); nitrobenzene and ethylene chloride (1:1); nitrobenzene; and chloroform. Of these the solution translucency stability of pentamethylidyne in chloroform and nitrobenzene was not as good as the ethylene chloride solution. In the experiments we

discovered that for nearly half a year the pentamethylidyne placed in the solution of ethylene chloride continued to be able to give good CPM wave forms and the translucence stability of the mixed solution was also good. This says that in these past few years China has become able to prepare rather stable pentamethylidyne dyes and solvents.

We believe that in the range of our experiments the solution of ethylene chloride with pentamethylidyne dye served as the most stable for CPM saturable absorption, had the narrowest mode-locked pulse, and good performance.

II. Saturable Absorbent Unidecamethylidyne

The absorption peak of unidecamethylidyne was at 0.98 μm, with translucivity very high at 1.06 μm.[2] We used propionic acid as a solvent and mixed a solution (1 mm thick dye box) with translucivity of 70 ~ 85 percent with respect to 1.01 μm (measured in a model 751 spectrophotometer) and did mode-locking and stability observations with the following results:

1. On a 500 MHz oscilloscope complete mode-locking CPM pulse sequences were observable (see Figure 2). However, the pulse stability and repeatability were both deficient. This was because the absorption peak of unidecamethylidyne was rather far from the laser central wave. In the vicinity of 1.06 μm the absorption coefficient is very sensitive to wave length variations.[2] Consequently when the oscillation central wave length has a minute change, the variation of its absorption coefficient is very prominent and since the laser output power is fixed, it is not easy to stabilize the output power and the repeatability also suffers.

Figure 2. CPM Pulse Sequence Image of Unidecamethylidyne in Propionic Acid

2. The total width of the pulse sequence is much greater than for the pentamethylidyne dye we tested (see Figure 2).

3. Because the translucivity of the mixed solution was higher, the non mode-locking threshold was lower, and the single pulse mode-locking zone was very narrow.

III. Saturable Absorbent BDN Dye Plate

In CPM systems, so as to have a more complete understanding of saturable absorption, we used a BDN plate (manufactured by the Tianjin Laser Institute) in place of a dye solution as a saturable absorbent. The BDN dye plate was 0.1 mm thick and T_0 was 46 percent. We placed it in the center of the ring

cavity (the place the dye box had been put). The results of the oscilloscope observations are as follows:

1. There was mode-locking but the mode-locking mass was not as much as with the pentamethylidyne solution (it was not complete mode-locking) (see Figure 3). The output energy was also weaker.

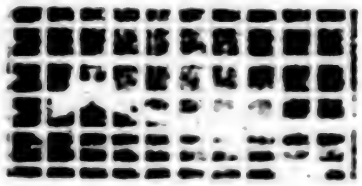


Figure 3. CPM Pulse Sequence Image With BDN Dye Plate as Saturable Absorbent

2. Similarly a single pulse mode-locking threshold was present. Under our experimental conditions, T_0 = 46 percent, the single pulse threshold value of the dye plate was 820V (100 μF) and when the pump source input was 970V or above, multiple pulse sequences would appear.

3. The total width of CPM mode-locking pulse sequences for the BDN dye plate was close to that of ethylene chloride solution of pentamethylidyne (about 120 ns). This conclusion shows that the CPM system is beneficial to operation of passive mode-locking.

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CSO: 4008/13

EXCIMER LASER CELL WITH LONGITUDINAL ELECTRON-BEAM EXCITATION

Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 6, No 6, Dec 86 pp 245-249

[Article by Guo Zhenhua [6753 2182 5478] of Huazhong University of Science and Technology, Wuhan, and F.K. Tittle and J. Liegel of Rice University, USA; received 4 September 1986]

[Text] Abstract: This paper describes an electron beam longitudinally pumped excimer laser. The magnetic field produced by a field coil and its effect on the electron beam is analyzed. A Current Viewing Resistor (CVR) and probe coil with integrater are used to study the magnetic field while a Faraday probe and diazochrome films are used to detect the position and spatial full width half magnitude (FWHM) values. With a graphite disc-calorimeter, the total energy of the electron beam is measured giving the tunable XeF (C→A) laser output.

In apparatuses where high energy electron beams (e.g., around 1 MeV) pump mixed gases producing laser oscillation, due to limits on the field effect diode cold cathode emission area (e.g., around 10 cm^2), the electron beam cross section of the transfer energy is subject to a fixed limit (around 2 X 10 cm^2). When the electron beam longitudinally pumps the laser material, its effective action distance is also restricted by the component's longitudinal dimensions (only 3-4 cm). Even if the component structures were capable of tolerating mixed gas pressures up to a magnitude of 12 atmospheres, the energy of the high speed electron beams still could not completely and effectively be transmitted to the laser medium. Instead the matter of the laser's walls (like stainless steel) stops and absorbs a portion of the energy. At experimental sites, harmful bremsstrahlung X-rays are produced.

In order effectively to inject high speed electron energy into the laser medium to produce as energetic a pulse as possible or to lengthen the activation medium as much as possible, producing new oscillation, it is necessary to lengthen the mutual interaction path between the electron and the medium particles, that is to increase the probability of collision between the electrons and the particles of the medium. To achieve this goal, the U.S. Sandia laboratory first set up a "λ" type longitudinal apparatus. The electron beam is emitted from an inclined tube and, having an effective

action distance of 50 cm, injects over 100 J of energy into Hg vapor [1]. West Germany's Niaoceboge University established a vertical tube type end input apparatus. The electron beam directly traverses a resonance cavity mirror going into the cavity. In the Ar-N_2 activation medium, it receives photo-oscillation of 406 nm [2]. The stainless steel, thin tube apparatus described in our paper was of length 100 cm, diameter 5.0 cm, with walls 0.08 cm thick. The relativistic electron beam was introduced from a branch tube (Figure 1). Separately, we used four external coils producing a magnetic field restraining the kinetic behavior of the electrons, making it so they were to advance along the axial line direction by a helical path in the laser medium reaction chamber. Consequently, the possibility of collision between the electrons and the mixed gas particles was vastly increased and the energy was effectively transferred to the laser medium.

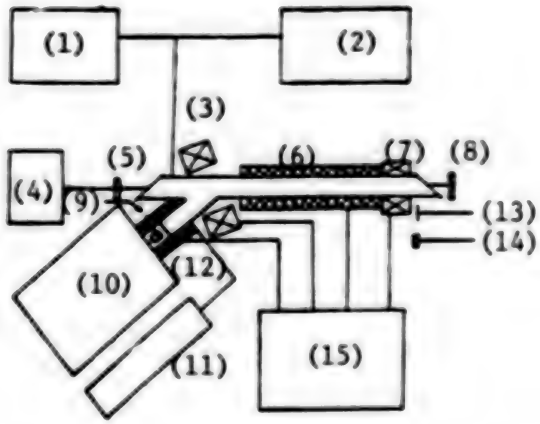

Figure 1. Excimer Laser With Longitudinally Pumped Electron Beam

Key:

1. Vacuum diagnostics
2. Aeration system
3. Adjustable deflection coil
4. Laser diagnostics
5. Output lens
6. Restraining helical tube
7. Deflection coil
8. Reflection mirror
9. Cathode
10. High energy electron generator
11. Vacuum system
12. Restraining coil
13. Electron beam diagnostics
14. Magnetic field diagnostics
15. Magnetic field power supply

Circuit for Producing the Magnetic Field

The basic circuit for producing the magnetic field was as shown in Figure 2a. The high voltage source, through a current limiting resister, stores energy charging the capacitor network C (750 μF, 5 KV). The Ross leakage circuit composed of R_D and the leakage switch is to ensure safe operation. It is a normally closed circuit. Only after the laboratory danger zone is locked and the safety light turned on is it closed to allow capacitor C to charge. The Snubber network composed of $R_S C_S$ is to prevent the LC system from producing rapid voltages when the trigger is suddenly opened. The two high voltage

diodes also are for safe operation. When the voltage reverses on the capacitor they conduct to prevent the reverse voltage from breaking down the capacitor when the trigger switch is closed. The current viewing resister (CVR) is made using a 0.6 time standard noninductive resistance. Its signal was measured on an oscilloscope. The components were arranged on both sides of a heat resistant, insulated, resin glass board which was installed in a specially made enclosure. There were two kinds of 5 KV direct current high voltage sources. One was a commercial voltage source with maximum current of 20 mA. The charging resistance was 250 KΩ and the charging time was about 180 seconds getting a bit longer with continuous experiments. The other was our own full wave rectified voltage source with maximum currents reaching 200 mA. The charging resistance used two resisters in parallel making 15 KΩ and the charging time was around 12 seconds. It was necessary to give special attention to the question of heat dissipation.

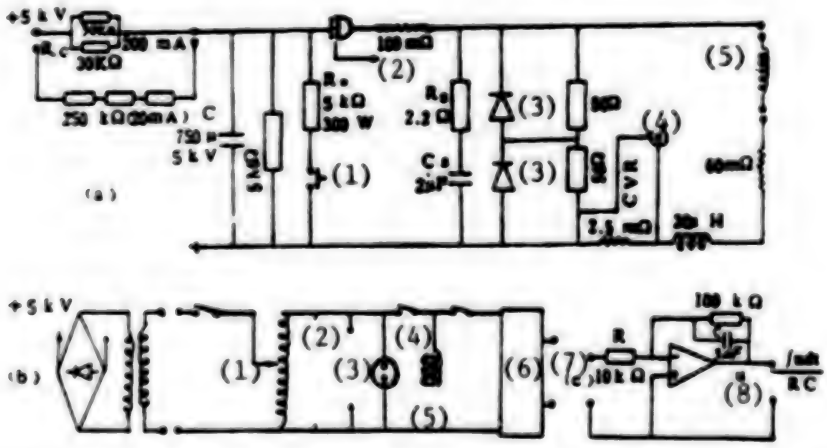

Figure 2. Circuit Key Diagrams: a) Magnetic Field Circuit, b) Control Circuit and Voltage Source Circuit, c) Coil Probe Circuit

Key:

(a)
1. Leakage return circuit switch
2. To trigger element
3. Diode
4. Oscilloscope
5. Magnetic field coil

(b)
1. Voltage regulator
2. To leakage switch
3. To trigger element
4. Indicator lamp
5. ?Return circuit
6. Voltage regulation network
7. City electricity
8. Output

The voltage source control network was as shown in Figure 2b. Through the relay it locks the path and experimental site, lights a red lamp, and charges and discharges according to programmed, safe operation. Under critical conditions it can automatically disconnect the voltage source and make the capacitors discharge. The thyrotron trigger element is a Maxwell type commercial product requiring input of a 5V, 1 ns pulse.

The magnetic field pulse width is on the order of ms and the electron beam pulse width is on the order of 10 ns. The triggering time matching between the two relies on an HP-214B model pulse generator for control. Simultaneous with giving its trigger output probe signal to the magnetic field circuit, its delay output probe puts out a suitably delayed pulse signal to the high voltage trigger network of a PIP 110 electron accelerator. Adjusting the delay time (about 1 to 2 ms) can make it so just as the magnetic field in the laser chamber reaches its peak value, the electron beam from the tube comes through and is effectively restrained. A block diagram of the entire experimental setup is given in Figure 3.

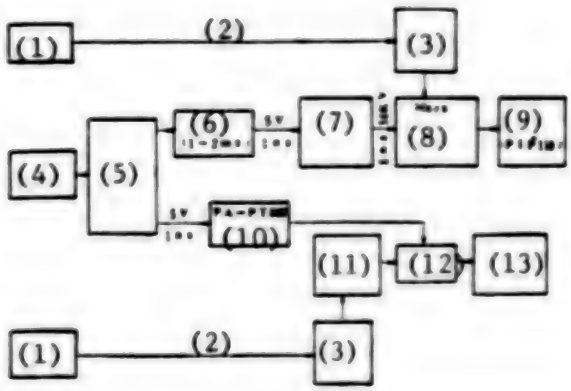

Figure 3. Block Diagram of the Experimental Setup

Key:

1. Remote control
2. Transmission line
3. Special voltage source
4. Manual push botton
5. Pulse generator
6. Delay (1-2 ms)
7. High voltage surge generator
8. Marx high voltage pulse generator
9. Field effect diode (PIP 110)
10. PA-PT003 trigger element
11. Storage capacitance
12. Ignition switch
13. Magnetic field coil

Calibration and Measurement

After the circuit conducts, the rise time for the current in the loaded magnetic field coil is determined by the circuit parameters, reaching an extreme value in roughly in 1 ms. Consequently, after about 1 ms the magnetic field of the helical tube's inner part (i.e., inside the stainless steel tube) also ought to attain a maximum value (Figure 4). The current variation is detected by a 2.5 MΩ standard resistance (CVR) in series with the loaded coil. The magnetic field is then obtained by directly using a probe coil to measure the magnetic flux within the tube. The change of the voltage signal obtained over time is sent to an R7912 storage oscilloscope and a digital transient analyzer with a microprocessor (PDP 11/23) and a plotter (HP 7225A) to carry out analysis. The maximum current measured by the CVR was I = 2.64 KA. From this we can compute the magnetic field, H, in the helical tube in the CGSE unit system to be

$$H = 4\pi nI \text{ (CGSE magnetic field units)}$$

in which n is the number of turns of the coil per centimeter (n = 3); I is the current in the CGSE system, the size of its numerical value is multiplied according to the multiplier c/10; c is the speed of light. The magnetic field intensity converted into the CGSM system is then

$$H = 4\pi n \left(\frac{C}{10}\right) I \cdot \left(\frac{1}{C}\right) \text{ oersteds (Oe)}$$

In the CGSM system, the magnetic induction intensity unit, the gauss, and the magnetic field intensity unit, the oersted, are equal. Consequently, for a gaseous medium we have

$$B_{CVR} = H = 4\pi n\ I/10 \quad \text{gauss}$$
$$= 9.94\ KG = 0.994 \quad \text{Tesla}$$

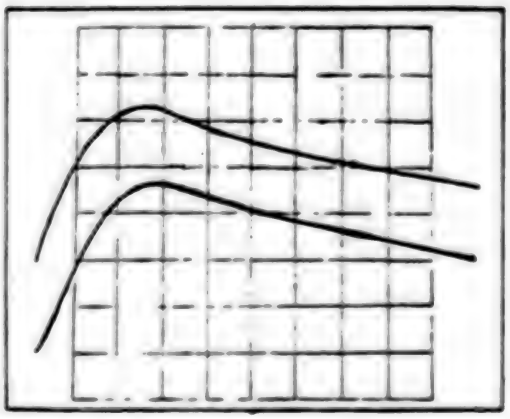

Figure 4. Oscilloscope Form Measured for the Magnetic Field in the Tube Cavity
Horizontal coordinates: 0.5 ms/grid
Vertical coordinates: upper line U_{CVR}, 2 V/grid
lower line U_{probe}, 50 mV/grid

To measure directly the magnetic flux we used a small probe coil. It was fixed to a wooden handle and its voltage output sent to an integrator circuit (Figure 2c) for which the time constant was 30 ms (10 KΩ X 3 μF). The probe coil's actual calibration parameters were: number of turns, N = 33, coil cross section s = 1.72 cm^2, and the actual time constant, τ = 39 ms was larger than the computed value. From this we calibrated out the quantitative relationship between the probe's output voltage and the magnetic induced intensity as B = 6.9 Tesla/V. From the wave form of Figure 4 we get

$$B_{probe} = 12.8\ KG = 1.28\ Tesla$$

and see that the two different measured results have a fixed difference. From Figure 5 we know that their variation tendencies are similar. That the probe coil measured value is 30 percent higher than B_{CVR} is possibly caused by systematic errors present in the integrator calibration. However, the biggest

advantage of using the probe coil is that it can be used to examine the relative changes in the magnetic field in different places inside the tube and it is capable of detecting magnetic field distortion at the laser flange entrance or in the coil's direction of change. This way through measures such as changing the helical tube's position and improving the spacing of the entrance and the seal we can make the magnetic field change uniform.

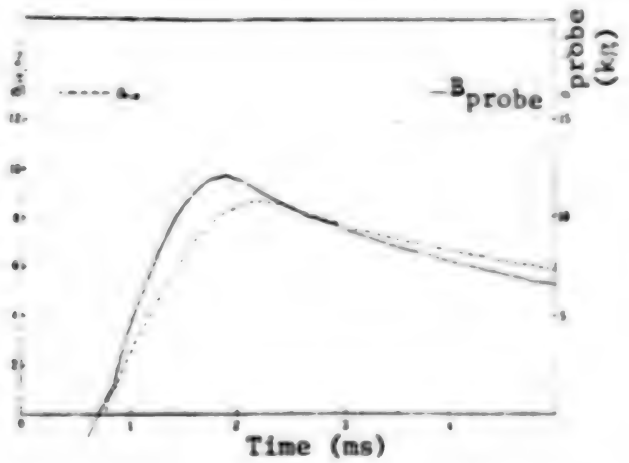

Figure 5. Variation of the Magnetic Field in the Cavity Over Time

Now, for a magnetic field of 9.94 KG we compute the restraining action on the high energy electrons. Because the electron energy is extremely high, it is necessary to use the relativistic formula to compute their velocity, v. Using the electron rest energy, $m_0c^2 = 0.5$ MeV can simplify the computations, i.e., the electron kinetic energy is $= \frac{m_0 c^2}{\sqrt{1 - v^2/c^2}} - m_0c^2 = 1\ \text{MeV} = 2 m_0c^2$

solving gives $v = \sqrt{8/9} \cdot c\ (c = 3 \times 10^8 \text{m/s})$

Letting the component of v perpendicular to the direction of the magnetic field (i.e., the optical axis) be $v_\perp = \sqrt{8/9}\, c/2$, then we can get the helical radius, r, when the electrons move in the direction of the magnetic field following the helical line, to be

$$r = \frac{m_0 v_\perp}{\sqrt{1 - v_\perp^2/c^2}} \cdot \frac{1}{eB} \qquad (m)$$

Since m_0 is the electron rest mass of 9.1 X 10^{-31}(KG), e is the electron charge of 1.6 X 10^{-19}(C), and B is given in tesla, we have

$$r = 9.2 \times 10^{-4} \text{m} \approx 1\ \text{mm}$$

that is, the helical motion radius is on the order of a millimeter, sufficient to make the opportunities for electron collisions with the tube wall be very few. Consequently, the electrons are able within a sufficiently long axial

distance to have multiple collisions with the laser medium particles and transfer their own energy to the medium.

From Figure 1 we see that as soon as the electron beam is emitted from the cylindrical graphite cathode it is restricted by the magnetic field coil. Because of the wall thickness (~5 mm) and the diameter (~100 mm) of the cathode cavity, this portion of the coil windings are double layered, intensifying the magnetic field restraining force to keep the electron beam from scattering too much. When the electrons get to the mouth of the Y-pipe, a minute adjustment can deflect the coil making the high energy electrons turn toward the direction of the resonance cavity axis. In experimental craftsmanship, to achieve link is rather difficult. A tunable deflection coil apparatus was designed to enable us to finely adjust its position and pitch. To regulate the effect we used a probe coil in the fork mouth to do monitoring. After the electron beam was well led into the long tube we stopped the adjustment. Afterwards the position and pi of this adjustable coil was locked in place with screws and the helical tube and inner stainless steel tube were not closely matched up leaving a fixed gap between their walls so their relative positions could be finely adjusted. The magnetic field produced perpendicular to the optical axis by the Helmholtz coil (composed of two coils) in front of the far end optical cavity mirror leads electrons and other charged particles that reach this point toward the tube wall in order to avoid their colliding with the optical lens plates (the (Brinell) window or the reflector, prism, and grating during intercavity operation).

The graphic relationship between the electron beam transient wave form position and time variation of the magnetic field obtained using a Rogowski coil or Faraday probe is as shown in Figure 6. The relative synchronization between the electron beam production time and the magnetic field peak value time is extremely good. However, this result was not easily obtained. At the beginning, the delay output of the HP-214 pulse generator is unusable and the electron beam generator is always operating at the same time as the magnetic field circuit making the electron beam pulse always exhibit a lead over the magnetic field peak value rise in Figure 6. Later, only by getting rid of the N333 inline between the HP-214B and the trigger element of the magnetic field return circuit was the problem resolved where strong electromagnetic coupling with thyratron conduction made the electron beam generator operate prematurely.

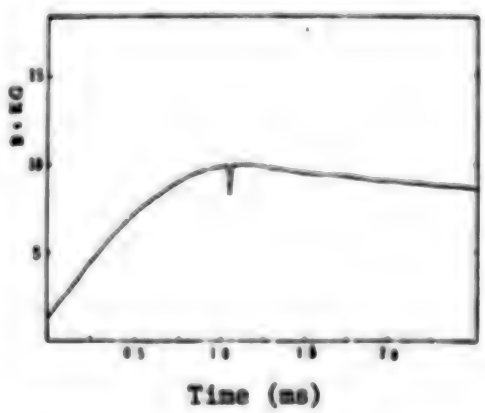

Figure 6. Synchronization Between the Magnetic Field and the Electron Beam

Discussion

When the entire setup was adjusted to an optimal state, we used a diazochrome film as target and surveyed the radial distribution of the electron beam in the tube, discovering it was a bell type distribution symmetric about the axis (FWHM = 2.7 cm).

There was a relationship between the energy of the electron beam injected into the laser medium and the pressure of the medium. Figure 7 gives an experimentally measured curve of electron beam injection energy and Ar pressure change when the magnetic induction intensity was 8 KG. From 2.5 atmospheres and above, the energy of each pulse injected into the medium exhibits saturation. For an Ar gas at 3 atmospheres we used a graphite disc calorimeter and a Cr-Al temperature difference thermocouple and measured the pulse injection energy as about 27 J. After improving the nonuniformity effects of the magnetic field, we estimate that this could reach 40 J.

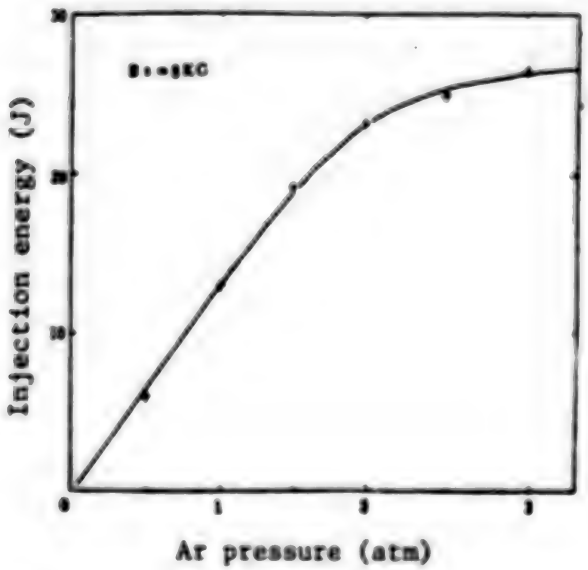

Figure 7. Relationship Between Electron Beam Injection Energy and Gas Pressure

The optical gain of many kinds of xinduo triatomic quasi-molecular medium computed by fluorescent materials is mostly 1-3% cm^{-1} or less. If the gain medium length is about 10 cm, then it is very difficult to compensate the various losses and attain the laser oscillation threshold so very seldom are laboratories capable of realizing such laser operation. The longitudinal electron beam pumping apparatus described in this paper expands the gain length to over 80 cm consequently increasing the one-shot gain capability around 8 times with output intensity increased e^8 times.

Research results of utilizing this longitudinal pumping apparatus on an XeF(C→A) quasi-molecular medium show that, not only does it achieve broad band laser oscillation (450 nm-530 nm) the same as a latitudially pumped

setup, also by using diffraction grating it can effectively compress line widths to about 1 nm as well as attain continuously adjustable laser output within a broad band. Figure 8 is a narrow band output laser corresponding to a wavelength of about λ = 488 nm. It was measured by fixing a diffraction grating inside the tube. The horizontal coordinate wavelengths were standardized using the separate spectral lines of an Ar^+ laser and were also checked using Hg lines.

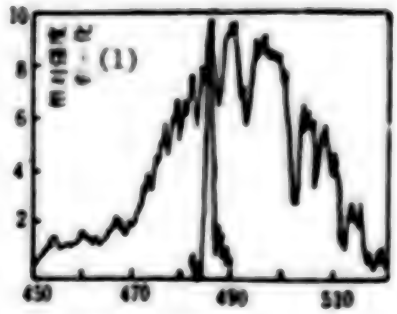

Figure 8. XeF(C→A) Laser Broad Band Oscillation and Narrow Band Tunable Output

Key:
1. Relative intensity normalized

For Xe_2Cl (central wavelength 520 nm) and Kr_2F (central wavelength 425 nm), the longitudinal apparatus can obtain laser oscillations similar to a latitudinal setup [4]. In addition, the possibilities are very good for using a longitudinal pumping apparatus to realize laser oscillations for Xe_2Br (central wavelength 420 nm), Xe_2I (central wavelength 375 nm), Kr_2Cl (central wavelength 325 nm) and other triatomic quasi-molecular media.

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12966/6091
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PHYSICAL DESIGN OF PARAMETERS OF Nd:YAG DISK LASER

Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 6, No 6, Dec 86 pp 256-258

[Article by Zhang Meizhen [1728 2734 3791], Cao Weilou [2580 3262 2869], Chen Qinghao [7115 1987 3185], and Tang Fulin [0781 4395 2651] of the Chinese Academy of Sciences, Shanghai Institute of Optics and Fine Mechanics; received 8 October 1986]

[Text] Abstract: Using a large Nd:YAG crystal grown by the temperature gradient method, we built a 40 mm aperture disk laser. The key problems that had to be resolved to set up the disk laser were suppression of parasitic oscillation in the disk and removal of waste thermal energy in the disk.

For some years now people have been continually striving to increase the average laser power and light intensity of Nd:YAG bar devices. However, due to limits on thermal conductivity and the effects of thermal double refraction, progress has been quite slow. Recently, the appearance of slab devices has greatly improved the quality of laser beams [1,2]. But because their surface areas are limited their output power has been small. In addition, the laser beams are rectangular, making it difficult to couple them with other systems. This paper gives the first report of a surface pumped, surface cooled disk Nd:YAG device. Because the pumping thermal gradient and the cooling gradient run along the optical axis, this fundamentally eliminates the influence of the thermal lens effect and thermal double refraction effects on the laser beam. Moreover, the surface area limit on power of disk devices is far higher than for rod or slab devices so by application of natural suitable technology, the work to fabricate kilowatt continuous or quasi-continuous devices approaching the diffraction limit and of 10,000 MW high repetition rate devices is already scheduled. Because the thickness of the working material of a disk is much smaller than its length (different from a slab, where the laser beam is directed along the width), the key technology to disk devices is suppressing the parasitic oscillations in the axis direction. In addition, because a surface cooling method is used, the effect of the cooling matter on beam quality is also a key question which must be considered.

In comparing garnet to glass we note that garnet's stimulated emission cross section is an order to magnitude higher than that of glass and that it also

Table 1. Properties of Laser Materials

		Nd,YAG	Nd,YLF_4	Q-98 Phosphate Niodymium Glass
Refraction rate	θ_0	1.82	$(1.45)_\pi$ $(1.47)_\sigma$	1.55
Laser wavelength	λ	1.064 μ, 1.052 μ	$(1.047\ \mu)_\pi$, $(1.053\ \mu)_\sigma$	1.053
Emission cross section	σ	$4.6\times10^{-19}cm^2$, $1.7\times10^{-19}cm^2$	$(6.3\times10^{-19}cm^2)_\pi$,$(1.8\times10^{-19}cm^2)\sigma$	$4.5\times10^{-20}cm$
Density	p	4.55 gr/cm^3	3.99 gr/cm^3	2.5 gr/cm^3
Thermal conductivity	K	0.13 W/cm – °K	0.06 W/cm – °K	0.01 W/cm – °K
Specific heat	c	0.59 J/gr – °K	0.79 J/gr–°K	1.2 J/gr – °K
Diffusion coefficient	k	0.048 cm^2/s	0.019 cm^2/s	0.003 cm^2/s
Thermal dissipation	α	$6.9\times10^{-6}°K^{-1}$	$(13\times10^{-6}°K^{-1})_A$, $(8\times10^{-6}°K^{-1})_C$	$8.2\times10^{-6}°K^{-1}$
	$(dn/dT)1.06\mu$	$7.3\times10^{-6}°K^{-1}$	$(-2.0\times10^{-6}°K^{-1})_A$, $(-4.3\times10^{-6}°K^{-1})_C$	
Nonlinear refraction rate	n_2	4.09×10^{-13}esu	0.59×10^{-13}esu	1.2×10^{-13}esu
Fluorescence lifetime	τ	(1%)2×10^{-4}s	(1.5%)4.8×10^{-4}s	(6%)2.7×10^{-4}s
Fluorescent line width	Δv	6 cm^{-1}	12.5 cm^{-1}	216 cm^{-1}
Damage threshold	D	10.1 GW/cm^2	18.9 GM/cm^2	8 GW/cm^2
	$F(=\sigma n_0/n_2)$	2.05×10^{-6}	15.2×10^{-6}	0.58×10^{-6}

has a fairly high damage threshold. These are all valuable advantages for making a high repetition frequency disk device (Table 1). From our 2 years of constructing large Nd:YAG crystals we have continually examined the physical problems of fabricating large aperture YAG devices and practical device design plans [3].

Using a large garnet crystal which we grew, we designed a 40 mm aperture high repetition frequency disk laser device (Figure 1). Two pieces of 6 X 40 X 80 mm garnet crystal were placed at their Brewster angle. We used four branch xenon lamp light pumps. The lamp tubes and electrodes were cooled using deionized water and the crystal used gas flow or heavy water for cooling. A laser bar cut along the direction of growth of an Nd:YAG crystal grown by the thermal gradient method possessed extremely fine optical qualities and laser properties [4]. Because the disk was large, we cut it along the direction of growth. The interference pattern, growth pattern, and mend point are as shown in Figure 2 and Figure 3. Crystal quality awaits further progress and improvements. This paper carries out computations of the physical parameters of the disk device. In the area of energy extraction and parasitic oscillation suppression, we used a technical approach the same as for a glass disk amplifier. The paper only discusses problems in the area of cooling and high repetition frequency operation of a large aperture high repetition frequency Nd:YAG disk laser.

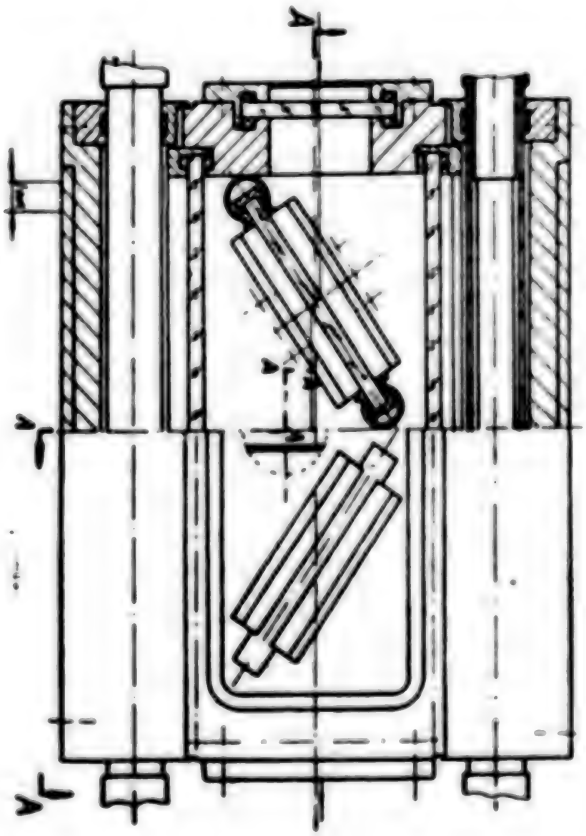
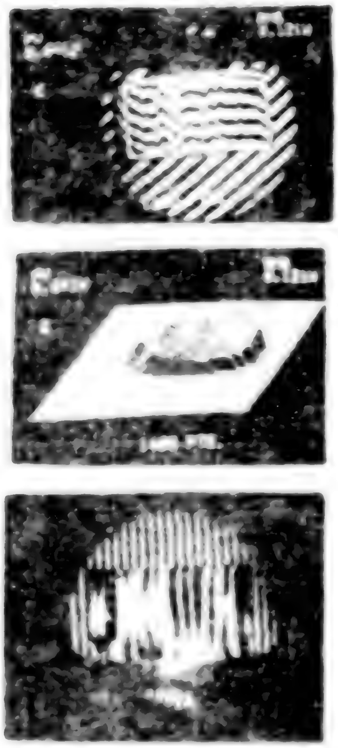


Figure 1. Nd:YAG Disk Laser Apparatus



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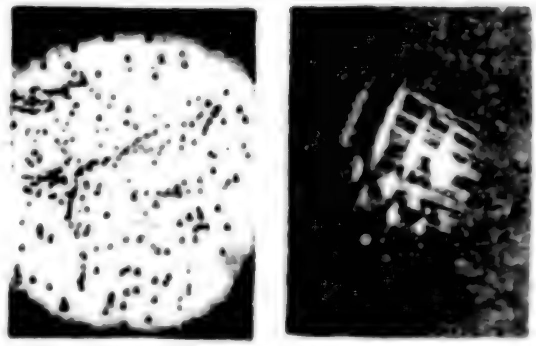

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laser disk (W/cm^3); and h is the thermal transmission coefficient of the disk with respect to the gas.

$$h = K_{gas} N_u / t_{gas}$$

Here N_u is the Nusselt number $\approx 1.54 \times 10^{-2} (Re)^{0.8}$; t_{gas} is the gas flow thickness; R_e is the gas Reynolds number $\sim 0.91 V t_{gas}$; and V is the gas flow velocity. K_{gas} is the thermal conductivity of the gas (W/cm-°K), for He this is 1.44×10^{-3} and for nitrogen it is 0.26×10^{-3}. Consequently we can compute the temperature rise.

Temperature Rise of the Gas and Dissipation of the Cooling Power

The temperature rise of the gas is provided by the following formula

$$\Delta T_{gas} = \frac{\xi f t_{YAG} l}{C_p \rho M V_s t_{gas}} \tag{2}$$

Where M is the Mach number (gas flow velocity); ξ is the thermal energy density in the disk; f is the pulse repetition frequency; l is the gas flow channel length (gas flow channel from the disk structure); C_p is the specific heat of the gas at fixed pressure; V_s is the speed of sound in the gas; and ρ is the gas density.

By providing just the parameter values, like the heat exchange dissipation, pumping frequency, pipe dissipation, and channel dissipation, then we can compute the work expended by the cooling system.

Stress in YAG

Since there is a temperature gradient from the inside of the disk to the surface, both the inside and the surface experience stress action. If the center of the disk is taken as the origin and the Z axis is perpendicular to the surface, then we have:

$$\sigma_x = \sigma_y = \frac{\alpha E \Delta T_c}{1 - \nu} \left(\frac{2Z}{t_{YAG}} - \frac{1}{3} \right) \tag{3}$$

Here σ_x, σ_y are the components of the stress; α is the thermal expansion coefficient; E is Young's modulus; and ν is the Poisson ratio. When $Z = t_{YAG}/2$, then

$$\sigma_s = \sigma_y = \frac{2 \alpha E \Delta T_c}{3(1 - \nu)} \tag{4}$$

From this we get that the surface stress of the disk is related only to temperature at the center and is not related to the thickness of the disk.

The disk Nd:YAG components we designed have already achieved laser output. Assessment of the various parameters and quality will be reported in separate paper.

We thank Zhou Yongzong for providing large Nd:YAG crystals for this experiment and Deng Peizhen and Qiao Jingwen for carrying out inspections of the Nd:YAG disks.

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INVESTIGATION OF BN CO_2 WAVE GUIDE LASER

Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 6, No 6, Dec 86 pp 262-264

[Article by Zhang Fuquan [1728 4395 3123], Zhang Zhonghua [1728 0022 5478], Liu Fengmei [0491 6646 2734], Wang Yusan [3769 7183 0003], Zhu Taixun [2612 1132 8113], and Zhao Jingshan [6392 2529 1472] of the Harbin Institute of Technology; received 5 August 1986]

[Text] Abstract: This paper reports on two kinds of CO_2 wave guide lasers constructed using boron nitride ceramic produced in China. One is a hollow cylinder CO_2 wave guide laser (1.6 X 100 mm) with output power of 700 mW. The other is a square CO_2 wave guide laser (1.5 X 1.5 X 150 mm^3) with output power of 1.5 W. Boron nitride ceramic has the advantages of good thermal conductivity and extremely low thermal expansion coefficient.

CO_2 wave guide lasers are small-volume, high-power laser devices that have attained broad applications to medicine, machinery processing, surveying, and laser radar. In heterodyne laser radars, lasers with wide tunable range and high stability are required. Boron nitride ceramic CO_2 wave guide lasers possess outstanding advantages in these areas. Having undertaken study of CO_2 lasers with BN as wave guide material, we attained the first operation of a CO_2 laser with BN ceramic produced in China used as wave guide material. BN is a new type wave guide material which exhibits fine electrical insulating and dielectric behavior. Its chemical and thermal stabilities are high. It can tolerate rapid heating and cooling below 1500°C and its thermal conductivity coefficient is high, second only to BeO in materials used for wave guides. Its machining performance is good with a surface polish that can reach ∇_{11}, higher than both BeO and Al_2O_3. It is inexpensive, nontoxic, and easier to work and apply than BeO. Its linear thermal expansion coefficient is small (less than 1 X 10^{-6}/°C), about 1/6 that of BeO and Al_2O_3, and the linear thermal expansion coefficient of thermocompressed BN ceramic can reach 1 X 10^{-7}/°C or less. This is beneficial to increasing stability of output and frequency. Under conditions where there is no tuning element control, it can stabilize operation at the predetermined energy level [1].

Basic Theory

The simulation with the lowest losses in wave guide lasers is the EH_{11} mixed simulation. We discuss this simulation below [2].

1. Transmission Loss of the Wave Guide Medium

Cylindrical:

$$\alpha_{11} = 0.1465 \frac{\lambda^2}{a^3} Re\left\{\frac{1}{2} \cdot \frac{\eta^2 + 1}{\sqrt{\eta^2 - 1}}\right\} \tag{1}$$

Rectangular:

$$\alpha_{11} = \frac{1}{16} \cdot \frac{\lambda^2}{a^3} Re\left\{\frac{\eta^2 + 1}{\sqrt{\eta^2 - 1}}\right\} \tag{2}$$

in which $\eta = \sqrt{\varepsilon/\varepsilon_0}$ is the relative refraction rate of the wave guide material, ε is the dielectric constant of the wave guide material, ε_0 is dielectric constant of the gas operating matter, λ is the operating wave length, and a is the radius or half the side length of the aperature. α_{11} is the speed of amplitude attenuation when describing the wave guide simulation with transmission along the wave direction with units of 1/cm or 1/m.

2. Coupling Loss

After a wave guide simulation (like the EH_{11} simulation) reaches the wave guide mouth it will radiate toward the free space. After reflection by the cavity plate, it cannot completely return to the same mode in the wave guide tube. At this time a coupling loss will appear which can be described using the magnitude of C_{11}. The approximation formula is:

$$C_{11} = 6.05 \left(\frac{Z}{Ka^2}\right)^{3/2} \tag{3}$$

in which Z is the distance from the mirror disk to the wave guide mouth, K is the wave vector, $K = 2\pi/\lambda$, and a is the wave guide radius or half the side length.

3. Transmission Loss Caused by Curves in the Wave Guide Tube [3]

$$\Delta\alpha_{11} = \alpha_{11} V_{11} \frac{a^2}{\lambda^2 R^2} \approx 19.3\left(\frac{a^2}{R^2\lambda^2}\right) \tag{4}$$

in which R is the radius of curvature of a linear curve in the wave guide, and V_{11} is the loss factor for an EH_{11} simulation.

4. Optimal Transmissivity Rate

$$t_m = \sqrt{2gL\alpha_0} - \alpha_0 \tag{5}$$

in which g is the small signal gain coefficient at the central frequency, L is the cavity length, and α_0 is the net loss back-and-forth.

5. Output Power

$$P = \frac{1}{2} AtI_s \left(\frac{2gL}{\alpha_0 + t} - 1 \right) \tag{6}$$

in which A is the effective cross section of the wave guide aperture, t is the transmissivity rate, and I_s is the saturation light intensity.

Device Design and Structure

1. We constructed two devices; one was a cylindrical CO_2 wave guide laser and the other was rectangular. The dimensions of the cylindrical wave guide were 1.6 mm X 100 mm. It had the advantage of sealing well but was difficult to process and so not easy to ensure flatness and smoothness. Based on formula (4) we know that a minute curvature in the wave guide will cause a rather large drop in output power [3]. Consequently, the processing demands on the cylinder are more stringent. For the processing of the cylinder we employed various methods to carry out tests and finally produced a relatively ideal cylinder.

The rectangular wave guide dimensions were 1.5 X 1.5 x 150 mm^3. Its advantage was ease of processing to ensure flatness and smoothness. However, because it was necessary to use glued connections, its seals were not as good as the cylindrical wave guide. On a block of BN ceramic we milled out a 1.5 X 1.5 mm^2 trench. After polishing, we covered the trench with a slab of BN ceramic, using sealer number 4 produced by Beijing Rubber Factory 12.

2. The cavity used by the two devices had on one side a metallic plated total reflector and on the other an antiabsorption and antireflection germanium with a transmissivity of 5 percent. The two mirrors were placed at the near ends of the wave guide mouths, forming an optical cavity. This structure is shown in Figure 1.

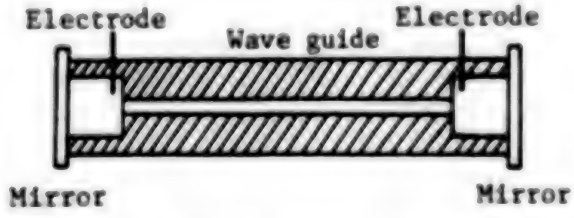

Figure 1. Wave Guide Tube Structure

3. These devices used the BN ceramic produced by the Zibo Specialty Ceramic Factory. Its density was rather low at 1.8 kg/cm^3 (foreign produced BN ceramic is 2.27 kg/cm^3). Also there were impurities included (where there are impurities, air can leak through). These factors both affect the vacuum of the device so it was necessary to undertake processing of the BN ceramic tube's surface to increase the seal and ensure the longevity of the devices. We did two experiments: In one we thinly spread a layer of glue on the surface and the vacuum could get to 2×10^{-5} Torr but the glue did not conduct that well which influenced the laser power output. In the other experiment we spread a coat of special lacquer and the vacuum could still reach 2×10^{-5} Torr but the output was more ideal.

We will now use the formulae given above to carry out computations for the designed device and thus demonstrate its practicality.

1. Gain. Using the gain formula:

$$g = \sigma \cdot \Delta N$$

in which σ is the excitation cross section, ΔN is the inverted particle concentration obtained by solving the speed equation. We calculated $g = 0.013\ cm^{-1}$.

2. Transmission loss. Cylindrical: Using the formula and taking $n = 2$, we get $\alpha_{11} = 4.6 \times 10^{-4}\ cm^{-1}$. Using formula (2), for the rectangular case we get $\alpha_{11} = 4.8 \times 10^{-4}\ cm^{-1}$.

3. Coupling loss. Using formula (3) we get for the cylindrical case, $C_{11} = 0.01$, and for the rectangular, $C_{11} = 0.011$.

4. Optimal transmissivity. Using formula (5) for the cylindrical case, $t_m = 0.06$, and for the rectangular, $t_m = 0.09$.

5. Output power. Using formula (6) we get, for the cylindrical case, 0.83 W, and for the rectangular, 1.38 W, in basic agreement with experimental results.

Experimental Results

Power measurements were done using an American (Xianggan) company power meter.

1. Rectangular Wave Guide

For different gas compositions we did experiments on the relationship between output power and total gas pressure. With $CO_2:N_2:He = 1:1:4$, we did experiments to get the variation of output power with current and the variation of output power with total gas pressure for different discharge currents, see Figures 2-4. The optimal gas ratio was 1:1:4 and the optimal discharge current was 6 mA. As Figure 4 shows, the maximum value of the output power was 1.5 W reached around 60 Torr.

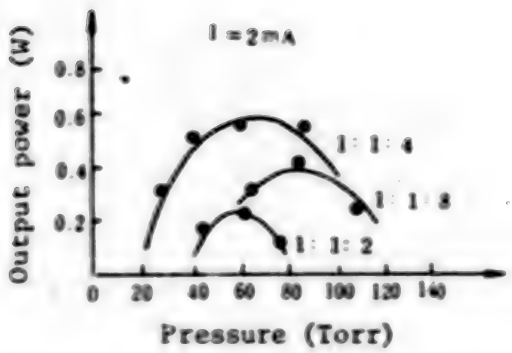

Figure 2. Output Power-Gas Pressure Curve

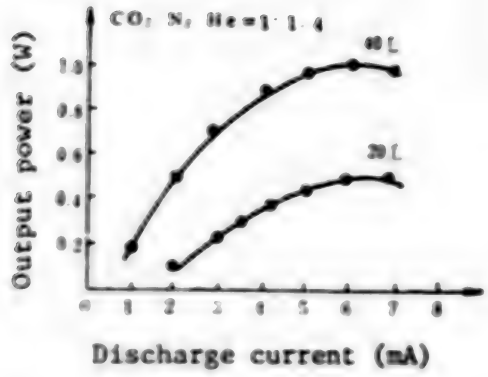

Figure 3. Output Power-Discharge Current

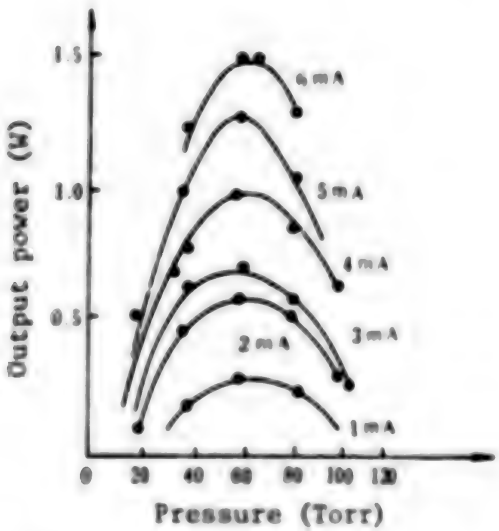

Figure 4. Output Power-Gas Pressure for Different Discharge Currents

2. Cylindrical Wave Guide

These results were similar to the above. For CO_2:N_2:He = 1:1.3:6, total pressure 60 Torr, and discharge current of 5 mA, the maximum output was 700 mW.

The experiments prove that domestically produced BN ceramic, after surface treatment to improve the vacuum and polishing of the inner surface of the wave guide to get an ideal smoothness, can be used as the material for CO_2 wave guide lasers.

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EXPERIMENTAL STUDY OF STABILIZING He-Ne LASER OUTPUT POWER WITH TRANSVERSE MAGNETIC FIELD

Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 6, No 6, Dec 86 pp 275-276, 274

[Article by Xu Shunchao [1776 7311 3390] and Lei Guojung [7191 0948 0689] (now working at the Changsha Shao Pass Electric Factory) of the Shanghai Institute of Laser Technology; received 28 January 1986]

[Text] Abstract: This paper introduces a new method for stabilizing the output power of an He-Ne laser (λ = 6328Å) by applying a variable transverse magnetic field to a portion of the discharge tube of the laser. This method can make the stability of the laser output power be better than 0.05 percent and yet the output power will not fall below the original level.

The power stability of lasers is an important condition of their application to the study of measurements since fluctuations in laser output power directly influence the precision of measurements. For this reason, in recent years many techniques for stabilizing laser power have been developed [1-4]. Of these methods, techniques to control the discharge current, to utilize Faraday effects, fan cooling, electric heating, and application of longitudinal magnetic fields have all been successfully used. The advantages of using techniques controlling the discharge current is that the stabilized interval is long and that it can be applied to tubes where the power fluctuations are rather large. The disadvantages are that this method reduces the output power by around 20 percent and that the constantly changing operating current can affect the longevity of the laser. Application of Faraday effect techniques is good for attaining high output stability for long operating intervals but has the problem of large power losses and being expensive. Fan cooling methods are good for the high degree of power stability achieved but such systems are complicated. The application of a transverse magnetic field as proposed by this paper to stabilize output power, besides having the good points of possessing a long stability interval and a simple control system, also overcome the faults of the above methods where the power falls. Experimental results show application of this method can, in situations where the laser output power rises slightly, give an output with rather high stability. Moreover, the laser can operate under constant current conditions extending its longevity.

Experimental Principles and Apparatus

Operating He-Ne lasers under a transverse magnetic field, transverse splitting can appear. For an inner cavity type He-Ne laser, because it operates in 2-3 longitudinal states, when a transverse magnetic field is applied, the principles of variation of the polarized light intensity along the magnetic field and that perpendicular to it are almost opposite. Thus, in a fixed magnetic field strength range, the polarized light intensity along the magnetic field varies with the size of the magnetic field. When the magnetic field continually increases, the polarized light intensity along the magnetic field can reach saturation [5].

For semi-external cavity He-Ne laser tubes, since there is only polarized light in a single direction, we applied a transverse magnetic field in the polarization direction and examined the relationship between output power and the strength of the applied magnetic field with the results shown in Figure 1. When the magnetic field was not applied, the laser output was located at point E on the curve. As the external magnetic field was increased, the laser output power gradually increased (the EF section) by 9 percent. When the magnetic field was increased even more, the output power fell linearly with the magnetic field increase (the ABC section). When the laser operated at point A, the external magnetic field was 240 gauss and the photoelectric receptor output was 53.5 mV. Operating at point B, the external magnetic field was 420 gauss and the photoelectric receptor output was 50 mV, the same laser output power as when the magnetic field was not applied. When the magnetic field was increased to 600 gauss, the photoelectric output was 46.5 mV. If the laser takes the point B as the control point, then utilizing the linear relationship of the ABC section and controlling the laser output by varying the magnitude of the applied transverse magnetic field, the goal of stabilized laser output power is achieved. In Figure 1 taking point B as reference, for conditions where the power fluctuations do not exceed ±7 percent, the process is capable of realizing stable output of power. If the laser power fluctuations exceed this range, the control system can lose control. Lasers presently sold commercially can all satisfy this condition a short time after burn-in operation.

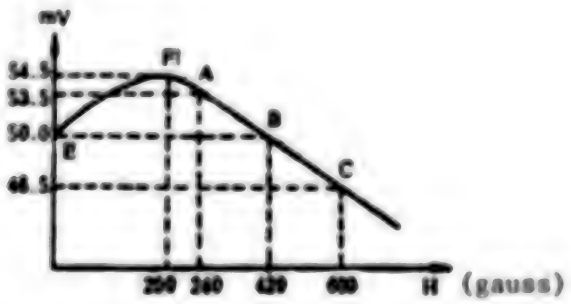

Figure 1. Effect of Applying a Transverse Magnetic Field Perpendicular to the Polarization Direction of a Semi-External Cavity He-Ne Laser

We used the apparatus diagrammed in Figure 2 to carry out stability experiments. After the laser had burned-in we regulated the steady flow voltage source to make the laser operate at discharge conditions of maximum output. We adjusted the position of a permanent magnet to make the magnetic field strength produced by it in the laser discharge zone be 420 gauss. The beam splitter was glass thin plate, making about 4 percent of the output laser energy go to photoelectric receptor 2 and passing 96 percent of the laser energy to photoelectric receptor 1 where variation in the laser output power was recorded. The size of the signal output from photoelectric receptor 2 is in proportion to the laser output power. This signal was fed to a control circuit. When the laser output power fell, the control circuit produced current in the magnetic coil so as to reduce the composite magnetic field produced by the electromagnet and the permanent magnet in the laser discharge zone and consequently raise the laser output power. Conversely, when the laser output had risen, the current produced in the control circuit was reversed and the composite mangetic field in the discharge zone increased to lower the laser output thus stabilizing the power at the control point.

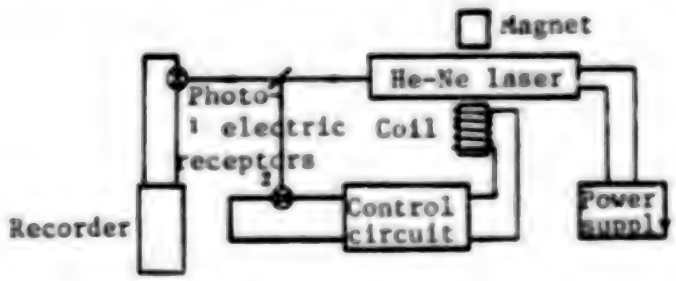

Figure 2. Diagram of the Experiment To Stabilize the Output Power of a He-Ne Laser

Experiment Results and Discussion

Figure 3 gives the results of a laser output power stability experiment. Section AB is where the operating current of the laser was 4 mA and the output power of the laser tube varied before application of the feedback control. Here power fluctuations were about 5 percent. Section BC is the laser output power (with the operating current still 4 mA) when the feedback control was applied. The laser output power stability was now better than 0.5 percent.

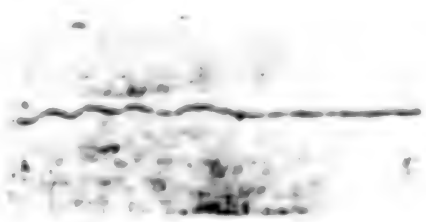

Figure 3. Laser Output Power Variation (1 grid/5 min)

Figure 4 is the variation curve of the laser output power before and after application of the feedback. Section AB is the situation when there is a dip in laser output power without feedback; BC is after the feedback is applied; and section CD is the situation for laser output after the feedback control is turned off again. Figure 4 shows clearly that the application of a transverse magnetic field to control the stability of laser output power is a very effective procedure.

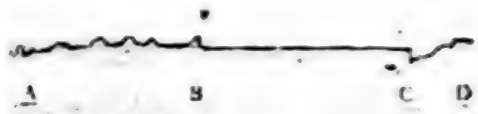

Figure 4. Clear Results of Applying a Transverse Magnetic Field To Stabilize Output Power of He-Ne Laser (1 grid/5 min)

The above experiments used a semi-external cavity quartz laser tube produced by the (Shangboyi) factory. Because the outer diameter of this laser tube was as large as 35 mm, it was much coarser than a discharge capillary tube (generally being 5 mm). This was extremely inconvenient for the application of a transverse magnetic field to control the output power of the laser, requiring the permanent magnet to have a very strong field and to be able to produce a relatively uniform magnetic field distribution in the discharge zone. In addition, this demanded that the controlling coil have a fairly large control current. This makes it so that in experiments the thermal effects of the control coil become a troublesome problem. Consequently, miniaturization, functionalizing, and use of laser tubes that do not have external apparatus becomes appropriate so the magnetic field can be applied directly to the two sides of the discharge capillary tube with even more outstanding results.

If the power variation of the laser itself is not large, then the entire system can operate in the EF section of Figure 1. This way the range of variation of the magnetic field is smaller, facilitating control and the output power of the laser can also be increased.

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STATUS, DEVELOPMENT OF LASER DEVICES IN CHINA

Shanghai YINGYONG JIGUANG [APPLIED LASER] in Chinese Vol 7, No 2, Apr 87 pp 49-53

[Article by Wo Xinneng [3087 2450 5174] of the Shanghai Institute of Optics and Fine Mechanics; received 1 November 1986. This paper was delivered at the International Conference on Lasers, 1986 (Orlando, Florida)]

[Text] Abstract: This paper summarizes the development in China of high power lasers, crystal lasers, semiconductor lasers, gas lasers, chemical lasers, free electron lasers, ultra-short pulse lasers, and tunable dye lasers. There is also some discussion of problems relating to further development of laser devices in China.

The first steps in laser technology research in China were made rather early with preparations begun in 1959. In September 1961, China's first ruby laser was completed, just 1 year later than in the United States [1]. Moreover this laser possessed uniquely Chinese characteristics. Subsequently, other types of lasers were constructed. Nearly simultaneously with other countries, the idea and methods for Q technology were proposed and, in 1963, China's first high power laser was constructed. Up to 1966, the disparity between Chinese laser technology and that of other countries was not great. In 1964 there was established the Chinese Academy of Science's Shanghai Institute of Optics and Fine Mechanics exclusively devoted to the study of laser technology and science. All along research on strong lasers and the development of new model lasers occupied a major place in Chinese laser technology research. Laser devices and practical research were also developed by many units throughout China.

I. High Power Lasers

1. High-power pulsed neodymium glass lasers. In 1963, the Shanghai Institute of Optics and Fine Mechanics used rotating mirror tunable Q methods to construct a ruby laser with an output energy of 0.2J and a pulse width of about 10 ns. By 1967, neodymium laser output energies had reached 1,000J and powers of 5×10^{10}W. In 1973, using clipped wave and an electro-optical tuned Q to shrink pulse widths to 2 ns, laser powers attained 1.5×10^{10}W. In 1974, multiple channel large model plate amplifiers raised output powers to 2×10^{11}W. In 1976, a six-path, high-power laser system with pulse width

of 1 ns and energy of 180J was constructed. Bombardment microsphere targets received a compression of nearly 30 times. After 1981, based on many physics experiments on laser demands and system self-stabilizing requirements, enhancements and improvements were made on six path subnanosecond neodymium glass laser systems making the output pulse width adjustable in four grades and the output wave form basically controllable as a smooth wave or a modulated wave form. The stability of the system's total operation was improved so that the output pulse width fluctuation was < ±20 percent and the peak value fluctuation was < 10 percent [2,3].

In the last few years, we have also paid attention to developing short wave length high power lasers with regard to problems of high efficiency, high power, and large aperture frequency multiplication in Nd lasers. Extensive research has been done with the goal of increasing the efficiency of laser and plasma interactions. We also use lens arrays to accomplish uniform illumination of a large focal area and methods of augmenting the frequency bandwidth to increase neodymium glass high power laser output power. Recently, China has successfully researched quasi-continuous prelaser tunable Q and pulsed prelaser tunable Q Nd:YAG and Nd:YLF oscillators. First, we resolved physical and technical problems of pulse prelaser tunable Q mono longitudinal mode oscillator cavity length and achieved long term, completely stable mono longitudinal mode operation. Through wave clipping and amplification, we attained ns, kJ magnitude laser giant pulses and used them to make a large model phosphorus glass laser system oscillator [4]. To serve as the operating substance in high power lasers, efforts are currently devoted to fabrication of phosphate-neodymium glass with low nonlinear refractivity coefficients and good lasing behavior. Using plate amplifier series, the maximum clear aperture is 200 mm [5].

Henceforth, the trend of development in Chinese high power lasers will be continued increases in output power and the development of various diagnostic testing means.

2. High power transverse current excitation continuous CO_2 lasers. China has constructed 5 kW magnitude CO_2 lasers. The devices are transverse flow closed circulation systems using form II folded single pass stable cavities with a total optical path of 3 m. The largest multiple mode laser output was 5.6 kW with a photoelectric efficiency of 12 percent. Outfitted with the necessary processing tools, this laser can carry out various thermal processing applications [6].

II. Crystal Lasers

1. Laser crystals. The production of laser crystals undertaken in China includes ruby, YAG, and YAP. The optical performance of these crystals has exhibited clear improvements and they have increased in size and end product rate.

The Czochralski method was used to fabricate high grade ruby laser crystals measuring 9 x 92 mm, with homogeneity < 1 striation/inch, scattering losses of 0.001 cm^{-1}, and doped with 0.05 percent Cr_2O_3. There are no inlaid

structures inside the crystals; the residual stress was small, and the dislocation density low. Using a small aperture selective transverse mode, TEM_{00} mode output can be obtained with a line width of 0.07 A [7]. The single rod output of a 28 x 1,000 mm ruby laser crystal was 3 kJ with a maximum efficiency of about 1 percent.

We have grown Nd:YAG crystals using the three techniques of induction heating, resistance heating, and temperature gradient methods and have closely studied the habits of crystal growth. For raw materials and crystal rods, treatment by the RAP (reaction atmosphere) method was carried out to increase the optical uniformity lasing efficiency of the laser rod. This increased by 28 percent the efficiency of growing the crystal compared to an increase of 10 percent with the method of high temperature annealing in the atmosphere. Laser crystal rods prepared using the yinshang method have an end product rate going over 50 percent of which optimal rods can reach 64 percent. We use the temperature gradient method to manufacture good optical quality, 50 x 62 mm Nd:YAG crystals with neodymium concentrations 0.9 - 1.3 (atoms) percent, displacement density $< 1 \times 10^2$ cm^{-2}, and refraction variation within $\lambda/2$. The lasing performance of these crystals is: slope efficiency 0.6 percent, maximum output power reaching 3.0 MW (pulse width of 10 ns), easily obtained stable single transverse mode output, and output energy of 2.8 mJ (input energy of 37J) in TEM_{00} mode (tuned Q) [8].

China has constructed Nd:YAP and Nd+Cr:YAP continuous lasers with output powers of 162W and 152W and efficiencies of 2.06 percent and 2.11 percent respectively. Our Nd:YAG 1.34 μm continuous laser has an output of 61.8W, efficiency of 1.15 percent, and slope efficiency of 2.02 percent. When outputting a single 1.3414 μm laser line, the output power is 61.8W, continuous operation 45 minutes, power stability about 1 percent, divergence about 10 mrad, and it is nearly linearly polarized [9]. In addition, with Nd+Cr:YAG crystals, continuous, pulsed, repeating frequency, Q switched, frequency multiplying, mode locking, and single mode laser operation has been achieved. We have discovered that Cr^3 in Nd:YAG not only has a sensitizing effect but also lowers the crystal's distortion, increases the fluorescence longevity, and enhances the crystal's ability to resist ultraviolet irradiation. Our first trials of a 9 x 30 x 70 mm plate device made with Nd:YAG crystal obtained a repetition frequency of 50 Hz, output energy of 0.7J for each pulse, and an average power of 35W [10]. We have made rare earth doped oxide and fluoride laser crystals as well as high concentration self-activating laser crystals. Prepared using the Czochralski method, large monocrystals of yttrium-lithium fluoride, yttrium-calcium fluoride, flurophosphoric acid calcium, silicon[?] oxide yttrium calcium, gadolinium moybdate, yttrium vanadate, and berydate lanthanium have all achieved laser operation. Lasing has also been obtained with neodymium and yttrium gallium garent crystals grown using the improved Czochralski method.

More than 60 rare earth phosphate crystals such as neodymium pentophosphate, neodymium tetraphosphate, $La_{0.1}Nd_{0.9}P_5O_{14}$, PrP_5O_{14}, HoP_5O_{14} have been made using the flux grown method. In addition, we have fabricated aluminum borate neodymium [$NdAl_3(BO_3)_4$] high neodymium concentration lasing crystals.

We have used the yinshang method to grow doped $Cr^{3+}:BeAl_2O_4$ laser crystals with a wave length tuning range of 720 - 780 nm and laser output line width of 8 Å. Using a $LiIO_3$ frequency multiplier, at 760 nm, the fundamental wave energy was 49 mJ and the frequency multiplied output was 0.5 mJ [11,12]. Through improvements in crystal quality, laser beams with nonscattering centers have been fabricated having an optical uniformity of 0.25 λ/inch. With an output coupling of 11 percent, the free oscillation lasing threshold was 34.1J, slope efficiency 0.6 percent, maximum output energy 800 mJ, and line width 0.4 Å. After using an $LiF:R^-$ center color center crystal tuning Q, the line width was less than 0.01 Å.

2. Color center crystals. Gains have also been made in the area of color center crystals (LiF, CaF_2:Li, NaF, KCl, etc.). China has, using γ-ray irradiating LiF crystals, produced F_2^+ and F_2 centers, obtaining 9,000 Å and 63,000 Å laser output. Under high irradiation doses producing F_2^- centers, using neodymium glass laser pumping $LiF:F_2^-$, F_2^- colored center laser oscillation was realized with output wave length peak values located at 1.12 - 1.116 μm, band widths over 1,000 cm^{-1}, maximum output energies of 100 mJ, and conversion efficiency of ~4 percent. Utilizing $LiF:F_2^-$ colored center crystals as tuning Q components it can be employed for long periods of time under high power and the performance is superior to KDP, $LiNbO_3$ and other crystals. $NaF:F_2^+$ and $NaF:(F_2^+)_A$ colored center crystals in high power ruby lasers achieve passive Q tuning. In addition, employing X-ray irradiated Tl^+:KCl monocrystals gives $F_A(II)$ centers and using 1.06 micron Nd:YAG lasers as pumping sources might provide laser radiation.

3. Nonlinear crystals. The new nonlinear optical crystals first discovered and grown in China are listed in Table 1. In order to meet the requirements of high power nuclear fusion, research was conducted on the relationship between frequency multiplier crystals conversion rates and the crystal length, phase matching angle, and fundamental wave laser power density. Using a 3 cm thick type II KDP crystal operating under a 42 mm laser beam with a power density of 0.27 GW/cm^2, results of 0.53 μm frequency multiplier laser external energy conversion attained 61.5 percent.

Problems that await resolution are China's primary reliance on artificial control in growing crystals, a low end product rate, high cost, and the poor quality of source material. The continual probing for new type laser materials will be a long, formidable task in area of Chinese solid state lasers.

III. Semiconductor Lasers

Development of semiconductor lasers and optical communications are closely related. In December 1963, a GaAs PN junction laser was constructed in China. In 1971, a GaAs/GaAlAs double hetrojunction laser was completed and, in 1975, a double hetrojunction GaAs semiconductor laser operating continuously at room temperature was made. Recently, using the seedless crystal gas state growing method, not requiring annealing or diffusion doping, we directly fabricated high quality $Pb_{1-x}Sn_xTe$ laser diodes with a threshold current of 4 A under 38°C. In the area of preparation techniques,

Table 1. Two New Nonlinear Optical Crystals Discovered in China

Name	Transparent range (Å)	Dimensions (mm)	Double refractivity Δn	Space group	Effective coefficient of second order harmonic production	Damage threshold (GW/cm^2)	Intrinsic absorption (nm)	Other properties	Applications
β-BaB_2O_4	1,900-25,000	10 x 8	0.12	R_3 (low temperature phase transparent)	3-6 times that of ADP	2	50-350, at 190 nm indirectly absorbent	Homogeneous, good anti-tidal properties, mechanical strength	Autocorrelation measuring of Ar^+ laser pulses
L-argine phosphate	2,400-15,000			P_{21} (no phase change under 112°C)	4.5 times KDP	1		Moisture proof capabilities good, hardness 2.7	As triple and quadruple frequency multipliers

we used the molecular beam extrapolation method to grow $Ga_{1-x}Al_xAs/GaAs$ double hetrojunction lasers. Moreover, narrow channel substrate strip GaAlAs/GaAs double hetrojunction single mode lasers have been made with spectral widths less than 0.3 Å. In GaAsP/InP double hetrojunction lasers of wavelength 1.3 μm have also been constructed. At present a 16 μm PbSnSe diode laser has also been completed with maximum operating temperature of 48°K, minimum threshold current of 64 mA, high and low frequencies corresponding to 13.7 μm and 19.1 μm, and a tunable range of 164.28 cm^{-1} [16].

IV. Gas Lasers

The earliest successful Chinese gas laser was the 1963 He-Ne laser. Subsequently, Ar^+, Kr^+, CO_2 molecule, TEA CO_2, pneumatic CO_2, N_2, XeF excimer, CO, XeBr, XeCl, HCN and other lasers were fabricated.

CO_2 construction work has achieved rather large results forming a complete set from high power CO_2 lasers to continuous wave output CO_2 wave guide lasers (Table 2). Excimer lasers have developed rapidly in China. We have made six excimer state laser systems with discharge pumping or relativistic electron beam excitation (ArF, KrCl, KrF, XeBr, XeCi, XeF). We also have Xe_2^* lasers with a radiated wavelength of 1,730 Å. We have constructed an HgBr dissociation laser and have carried out studies on its laser spectrum.

Using a high current pulsed electron beam excited KrF with total output of 2 KJ, at optimum operating pressure, the laser output energy attains 12.5J [12]. Using an X-ray pre-ion avalanche discharge XeCl laser we obtained a maximum output energy of 2J at a wavelength of 308 nm. The energy efficiency of the device was 2 percent [18].

Seven types of metallic vapor lasers (Au, Ag^+, Cu, Mn, Pb, S, and gold-copper mixes) have been made in China.

One aspect of subsequent work in the area of gas lasers in China is further improving the efficiency and longevity of ordinary lasers as well as reducing their cost. The other aspect is to continue extensive research on high power CO_2 lasers and on excimer lasers.

V. Chemical Lasers

In 1965, China built an HCl chemical laser. Subsequently, DF, HF pneumatic chemical lasers and iodine atom lasers were constructed. In 1978, using a thermal initiation high frequency DF laser we obtained laser power with continuous wave output in the kW magnitude. Using an electron beam initiation pulsed high frequency DF laser, the output energy density was 41.3J/l·Atm. In 1983 using an electric initiation HF, laser output energy was 1J, the pulse width was 100 ns (total pressure 120 torr), and electrical efficiency was 3 percent. In 1985, frequency selection operation was successfully carried out for HF/DF. Chemical lasers are the weak link in the laser field in China.

Table 2. Types of CO_2 Lasers Constructed in China

CO_2 laser	Output power	Operating mode	Efficiency	Operating pressure	Gain coefficient g	Other
Cooled electron beam controlled	430J	Multiple mode direction angle ~1 mrad	11%		$\geq$ 4.5%	
Heated electron beam controlled	Maximum energy density 30J/l·Atm			Ratio of primary discharge electric field to pressure E/D=5 volts/cm·torr		Output aperture 80 mm; resonance cavity spacing 1.3 m
Ultraviolet optical pre-ion TEA					3.8% cm	
Repeating pulsed pre-ion TEA	5-6J (input 85J)	Homogeneous discharge frequency > 100 (gas filled once)	~7%	Long term stable operating pressure 660 Torr		Long term stable
TEA pneumatic mode locked	Modulated 0.2J unmodulated 0.5J	1-2 ns stable pulse series		660 Torr		Resonance cavity length 2344±5 mm
Small, sealed style long lived	200 mJ	Cavity length 320 mm, free potential plate corona pre-ions		H_2 5%		Discharge length 200 mm, life time 10^6 times
Sealed style long lived	25-30W	Discharge length 800 mm				Life time > 10,000 hours
Folded cavity immersed style	600W		15.44%			Power fluctuation < ± 2.5%

VI. Free Electron Lasers

Raman free electron lasers have been built in China. The electron beams for these lasers are emitted from a modified EB-1 model high current pulsed electron accelerator with a voltage of 0.5 MV, current of 50 kA, and pulse width of 60 ns. Employing a right handed rotation, circularly polarized electromagnetic undulator (period λ_w = 2.2 cm), or an axial symmetric iron annulus undulator (period λ_w = 2.25 cm) as pumping source, we obtained free electron laser emission [20] with FWHM about 20 ns, average power 0.5 MW, electron efficiency of 0.1 percent, and a wave length of 8 mm (K_a band).

The course of development of free electron lasers in China is headed toward shortwave lasers and applications for these devices.

VII. Ultra Short Pulsed Lasers

In 1985, Chinese work on ultra short pulsed lasers achieved results simultaneously in four research groups. All the groups employed collision pulse mode locking techniques: (a) In laser cavities carrying a nonresonant ring, an Nd:YAG and an ethylene chloride solution of saturable absorber dye, with the operating parameters optimized, provided a minimum output pulse of ~8 ps, with series pulse energy of 2.6 mJ, and output energy stability of ±9 percent [21]. (b) Using the 514.5 nm lasing of an argon ion laser as pumping light, output power of 3-5W, dye jet rhodamine 6 G as gain medium, and mode locking dye DODCI as saturable absorber medium, when the DODCI jet thickness was 20 μm, the concentration was 6.2 x 10^{-4}M, the mode locking laser pulse width 75-125 fs, and, under optimal conditions, the wavelength was 625 nm, and average power of each beam 22 mW.

Just from the results achieved to date, it is evident that the technology and equipment for production and detection of ultra short optical pulses in China already has attained a respectable level. Future advances will take place on this basis, continuing to develop even shorter pulses. This will require, on the one hand, undertaking more compression of laser pulses in present bands to approach the limiting value and, on the other hand, developing ultra short pulse laser technology for even shorter wave lengths all in expectation of achieving shorter laser pulses. This will be a rather difficult task. In addition, we should increase output power as well as functionalizing and universalizing these devices. At the same time we should emphasize and expand research of various application topics.

VIII. Dye Lasers

Recently Chinese work on tunable dye lasers has advanced rapidly. Already constructed is a high power, high quality, narrow band, pulse repetition rate, auto sweeping tunable dye laser with amplifier stage prism diffusion beam, grating tuning, and longitudinal or transverse pumping. It is formed from a dye oscillator stage, amplifier stage, and YAG frequency multiplication frequency tripler pumping system. The tunable range was 425-760 nm with peak value power of 5 kW-2 MW.

We have moved the laser tunable band toward the shorter wavelengths, building a series of ultraviolet tunable dye lasers. For example: 1) Four new types of 7-alkyl oxide-4-methyl cumarin dye [22], using N_2 laser pumping extends the tunable range to the ultraviolet zone shorter than 390 nm with a tuning width of about 500 Å. 2) 39 kinds of 2.6-dual substitution phenyl benzene and dioxazole compounds (DPDO) which are para, meta, and ortho substituted on a phenyl base. Of these, the vast majority were first synthesized in China [23]. Using N_2 laser pumping, the tunable range was 371-395 nm and the conversion efficiency 8-11 percent. 3) 2-substitution phenyl-5-biphenyl ozaxole (PBO) derivatives [24], have a tunable range of 378-429 nm, conversion efficiency of 17.3-22.8 percent, and possess fine optical stability.

Conclusion

It is evident from the foregoing that laser technology in China has advanced from modeling to the place where for individual devices and materials we have made our own innovations such as crystal frequency multipliers, dye lasers etc. What will subsequent developments be like?

1. Continue combining of various important application problems (e.g., laser plasma physics, laser isotope separation, laser optical fiber communications, cancer treatment, etc.) and developing laser devices.

2. In coordination with application topics in agriculture and industry (e.g., laser breeding, laser machining, laser heat treatment, laser surveying, etc.) enhance the performance of existing lasers and increase their output and efficiency.

3. Develop new types of lasers (e.g., free electron lasers, X-ray lasers, ultra short pulse lasers, etc.) and new devices in combination with new applications (e.g., new devices required in laser chemistry, laser spectroscopy and other applications).

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SCIENCE AND TECHNOLOGY COMMISSION OFFERS NEW 'SPARK' AWARD

OW0211122 Beijing XINHUA in English 0953 GMT 2 Jul 87

[Text] Beijing, 2 Jul (XINHUA)--China's State Science and Technology Commission has established a new award--the "spark award"--to encourage scientific workers and units who have made marked contributions to the development of rural enterprises.

This was announced by the commission's general secretary, Wu Wufeng, at a news briefing here today.

In 1985, the commission worked out a plan for technological development to boost the local economy. The plan, called the "spark program", aims to spread suitable technology to rural areas, raise the technical level of farming, farm produce and sideline product processing, and rural enterprises.

Wu said that so far several thousand projects have been listed in the "spark program" across the country, with a total investment of 2.3 billion yuan from the central and local authorities. Some of the projects have produced remarkable economic and social benefits, he said.

For instance, Shanghai municipality arranged 21 such projects last year, and 18 of them have been put into production and turned out nine million yuan in profits and taxes to the state. In Liaoning Province, northeast China, 20 "spark" projects last year yielded a combined output value of 74 million yuan, including 19 million yuan in profits handed over to the state.

Wu Wufeng said the "spark award" will go to those individuals and units who have contributed greatly to technological development, technical personnel training and project management in the "spark program", and to outstanding young people and model rural enterprises.

Scientists who have worked for a long period of time in rural areas and have made major contributions will be given a special aware, Wu said.

In order to encourage initiative and creativeness among scientific workers, and combine science and technology with economic construction, Chian has set up several types of awards, including awards for major achievements in natural sciences, for inventions and for technical improvements.

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CSO: 4010/62

METALLURGICAL EQUIPMENT SAID TO MEET WORLD STANDARDS

OW060916 Beijing XINHUA in English 0548 GMT 6 Jul 87

[Text] Beijing (CEI)--China's metallurgical equipment, capable of handling 10 million tons in open-air mining is now up to international standards, with some machines now available on the international market.

Spare parts for the 154-ton electric self-emptying trucks manufactured by a Chinese plant jointly with an American company are now being exported to 20 countries, including the United States, Canada, Australia, Norway, Brazil, Yugoslavia and Zaire.

The 250,310, and 380 millimeter tooth-cog drilling machines and point drills designed and manufactured in China offer the same functions and life-expectancy of similar machines produced abroad. These machines are now available on the market in the United States, Norway, Spain, Australia and Peru.

The China Metallurgical Import-export Corporation will display its whole range of equipment at the 1987 Australian international mining and exploration exhibition from 6 to 11 July.

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PLA S&T RESEARCHERS SUPPORT CIVILIAN PROJECTS

OW181736 Beijing XINHUA in English 1340 GMT 8 Jul 87

[Text] Beijing, 8 Jul (XINHUA)--Researchers at the commission of science and technology for national defence are helping in industrial and other projects of key importance to China's economic development, XINHUA learned today.

Between January and June, they accepted 329 such projects, on the basis of the 585 completed last year, benefiting 28 of the 29 provinces, municipalities and autonomous regions on the mainland, said a commission official.

"In implementing the policy of gearing military research forces to work on civilian projects, we concentrate on projects which involve use of high technology or are urgently needed by the country," he added.

Commission researchers have designed and built a computerized management information system for the Maoming oilfield in Guangdong Province, one of China's leading oil products exporters.

With the newly-built system, the official said, the oilfield has achieved automation in production control, resulting in savings of manpower and materials.

An institute of the commission is now working with the Panzhihua Iron and Steel Company in Sichuan Province to install a computerized management system. One of China's largest, Panzhihua was designed and built entirely by the country itself.

A commission school is negotiating with the Shanghai Jinshan chemical works, also one of China's largest and best, on the designing and building of a computerized management control system for one of the works' plants, the official said.

While working on key industrial projects, commission researchers have in recent years trained 50,000 technicians and specialists of systems engineering, computer technology and enterprise management, the official said.

"Transfer of technology to civilian industries is also the commission's task," he said, citing the example of a township paper-making mill in Pingjiang County, Hunan Province, which was on the verge of bankruptcy before commission researchers stepped in to help.

The researchers helped the mill solve its problem of sewage treatment, enabling it to produce mica paper which sells well in China and outside, the official said.

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CSO: 4010/62

NATIONAL SEISMIC CENTER UNDER CONSTRUCTION

OW100154 Beijing XINHUA in English 0101 GMT 10 Jul 87

[Text] Beijing, 10 Jul (XINHUA)--Construction of the National Seismic Data Telemetry and Processing Center is in full swing, according to the State Seismological Bureau here today.

The Beijing-based project includes a system for quick-monitoring the epicenters and intensities of major earthquakes of over six magnitude (richter scale) in China and those of over seven magnitude abroad.

A bureau official said so far his bureau needs five hours to circulate a notice of major earthquakes erupting abroad and three hours for those at home. Once the project is completed, the monitoring time for strong earthquakes both at home and abroad would be shortened to about one hour.

Since the work on the project started in 1985, the center's computer buildings, and the installation and debugging of the imported equipment have been completed, a computing system for seismic data is now in operation.

The center, a key project undertaken by the state seismological bureau, aims to intensify earthquake monitoring, prediction and research, the official said. It is composed of three systems: one for quick-monitoring strong earthquakes, one for observing pre-seismic indicators in the Beijing-Tianjin-Tangshan-Zhangjiakou region, and a national seismic data base and computing system.

The quick-monitoring strong earthquake system has 16 observation stations across the country, forming a nationwide observation network to collect and process strong earthquake data for timely warning to the public.

The Beijing-Tianjin-Tangshan-Zhangjiakou region, one of China's worst earthquake-prone areas, covers an area of 120,000 sq km; when the system observing the region is completed, earthquakes of over 3.5 magnitude hitting the region will be quickly measured, and observation data and pre-seismic indicators will be recorded for further studies.

The project is expected to be finished next year, the official said, adding that its completion will certainly update the country's earthquake monitoring technology and play a role in earthquake forecasts and research, as well as in mitigating earthquake damage.

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CSO: 4010/62

PROBLEMS STILL NOTED FOR S&T PERSONNEL MOVEMENTS

Tianjin JISHU SHICHANG BAO in Chinese 7 Feb 87 p 1

[Report by the Jilin S&T Commission: "Problems in Urgent Need of Resolution Regarding the Exchange of Skilled Personnel"]

[Text] Recently, at the Market for S&T Skilled Personnel Exchanges founded and run by the Jilin Provincial Conference on Linking up S&T with Production and Technology Exchanges, within a 10-day period more than 1,200 scientific and technical personnel were received, from whom 296 accepted employment, 75 were recommended to employing units, 21 projects accepted bids from township enterprises, 11 people bid, and 29 firms asked to register factories. Through this "window" we can see that there are still some problems in need of resolution regarding the movement of skilled personnel, and these problems should be noted by all areas.

One problem is the way of thinking from old and "leftist" traditional concepts that is confining people. Within some institutes and institutions of higher learning, there is a clear emphasis on theory and a disregard for application; there is an emphasis on the basic and a traditional concept that disregards development. In dissemination and promotion, people seldom treat the economic results obtained from applications as important conditions, and therefore the young are unwilling to go to the basic levels.

A second problem is that the current cadre management system binds the freedom of movement for scientists and technicians, and closed "unit and departmental ownership" restricts the development of the abilities and wisdom of scientific and technical personnel. Some leaders are anxious about the movement of scientists and technicians, that this will weaken the technical capacity of their own units; some fear that scientific and technical personnel will go "in droves," which would bring about the "hat" characterizing a disrespect for knowledge and a disrespect for skilled personnel and which would affect the reputations of the unit and the individual; and some would even rather confine scientists and technicians who have insufficient tasks or who have no tasks at all, but are willing to release them.

A third problem is that we lack policies that encourage the fulfillment of preferances for skilled personnel. People have said: "When policies are on the right track, skilled personnel flow toward the bottom; when policies are not right,

skilled personnel rise to the top; when policies are not spoken of, skilled personnel leave." Some technical personnel have technologies in their hands, or have achievements, and are quite willing to apply these things in society, but there are no corresponding policies. The majority of S&T personnel dare not bring up their own concerns and needs to leaders in fear that they will thereby be treated unjustly. Even though some bravely express to their leaders their desire to change jobs or to quit this one, without corresponding policies, the leaders will not allow this. In this way, all these leaders can do is to hope for technical achievements, their hearts being without pity.

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DETAILS PROVIDED ON HUNAN S&T RESTRUCTURING EFFORTS

Tianjin JISHU SHICHANG BAO in Chinese 7 Feb 87 p 1

[Report by Yang Songqiao [2799 2646 2890]: "Hunan Province Actively Promotes the Restructuring of the Science and Technology System"]

[Text] The Hunan Province Science and Technology Commission recently held a press conference at which the provincial S&T commission chairman Tao Min [7118 2404] said that 1987 would be a year of intensified restructuring of the science and technology system. The focal points of the restructuring would be on unleashing scientific research organizations, unleashing S&T personnel, and further strengthening the vitality and vigor of the scientific research organizations to mobilize the enthusiasm and creativity of scientists and technicians.

He said that last year among 185 scientific research organizations at the prefectural and city levels or above throughout the province, 81 units had implemented technology contract systems, and 23 units had implemented responsibility for expenses. The movement of personnel has had a good beginning, and more than 1,100 scientists and technicians throughout the province have left their former units to initiate, lead, or contract to enterprises, or to initiate civilian-run research organizations.

Tao Min also said that the chief measure for restructuring the science and technology system in Hunan Province for 1987 would be implementation of a separation of administration and research responsibilities in the unleashing of scientific research organizations. They will encourage and support technology development research units to incorporate into enterprises and to develop into professional technology development centers or research and production enterprises, and to implement the unification of research and production in various ways. All scientific research organizations that incorporate into enterprises or into enterprise groups will still be allocated research operating expenses, and capital construction investment projects that have already been determined will not be changed. Technology development scientific research units that have not yeat been incorporated into enterprises or into enterprise groups will continue to practice methods for reducing research expenses, and this year these will be reduced another 10 percent. Those institutes or affiliated offices or groups, the operations of which have not been good, where results have been lacking, or where the scale of fixed

assets is not great, will be permitted to contract or lease out as groups or as individuals. Institutes and academies of a greater scale and more powerful integration will be permitted to split into smaller accounting units, to implement categorical management, and one part of them may also contract or lease out by groups or as individuals. At the same time as this, the systems will continue to implement and perfect institute director responsibility systems where the institute director has the authority to decide the facilities and the tasks of middle-level administrative and technical cadre for his units and organization; he will have the authority to raise wages for staff members who have made greater contributions, and to control promotions within 3 percent of the total number of staff members each year.

In the area of unleashing scientists and technicians, he said that for all scientific and technical personnel who volunteer to work in the countryside or in impoverished regions of the frontier, in general the unit should permit this, and the individual should be preferentially rewarded. It is permitted that the technology of these scientists and technicians be shared among them through stockholding, and it is permitted that under the premise of working for profits on behalf of the state, society, and the public, some individuals will become wealthy before others. National professional technical cadre who go to small and medium-size towns, the countryside, frontier areas, townships, and group enterprises to work can similarly implement technical professional employment systems. Those scientists and technicians who make major contributions in their work, in accordance with the limits of their evaluation authorities, exceptions can be made to employ them directly in specialized technical posts. Regarding compensation for scientists and technicians who in their spare time engage in technical consulting, or that is received from the transfer of rights to off-dutty technical achievements, except for those portions that are taxed in accordance with laws and that are turned over to units in accordance with contract stipulations, the remainder shall remain with them.

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UNIFIED MANAGEMENT SYSTEM FOR S&T ENTERPRISE NOTED

Beijing KEJI RIBAO in Chinese 10 Feb 87 p 1

[Report by Zheng Haining [6774 3189 1337] and Tang Shifen [0781 1102 5358]: "'Kehai' Implements a Science-industry-commercie-education Unified Management Mechanism"]

[Text] The economic association formed by the Chinese Academy of Sciences (CAS) and Beijing Municipality's Haidian District--the Kehai New Technologies Joint Development Center--for 3 years now has turned over tax profits of 2.74 million yuan to the state, profits of 1.8 million yuan to CAS, 1.17 million yuan to the concerned institutes, and 193,000 yuan to subsidize social, cultural and education expenses, and has contributed 13,700 yuan per person to the state each year. In 1986, operating income for the entire center reached 40 million yuan, a growth of 25 percent over 1985.

"Kehai" has implemented a management mechanism that unifies the four areas of science and technology, industry, commerce, and education, where the axis is to manage technology achievements, where development is used to promote the large-scale emergence of achievements from new technologies, where technology training promotes the application of new technical achievements, and where service is used to perfect the entire process of the circulation of technology commodities.

"Kehai" uses three methods to disseminate technological achievements: directly disseminating the research achievements of institutes and higher institutions to production units; by forming products through development by the "Kehai" development department, the rigths to technologies are transferred to factories, or are directly entered into the marketplace; and after "maturing" in intermediate testing plants, the rights to achievements are then transferred to the factories or directly into the marketplace. Over the last 3 years, "Kehai" has obtained 94 achievements through development, and among the 74 that have been disseminated or applied, 9 are of an advanced domestic level, 1 has reached an internationally advanced level, and 3 have filled domestic voids. Of 15 development projects arranged in 1986, the technology development tasking for each has been accomplished, and 6 saw results from their development in the same year. The large-scale linear cutting tool automatic-programming system and microcomputer automatic control system developed by the Mechanical Control Laboratory run jointly by "Kehai" and CAS passed its ministry level evaluation in June 1986, the performance for which was of an internationally advance level.

"Kehai" has closely integrated development and service, and has placed social results in a primary position, which allows for a broader scope of service and higher qua ity. All "Kehai" products implement the "three fixed responsibilities and even though these may not be products sold by "Kehai," as long as the customer wants them, they will be responsible for repairs at a reasonable fee. In 1986, "Kehai" repaired more than 2,000 computers in areas throughout the country and supplied customers with more than 10,000 types of parts and components, or more than 300,000 at a price of more than 2 million yuan. The complete service offered by the "Kehai" system has been warmly welcomed by customers. Technical consulting is another item in the social services of "Kehai." Through various means such as retail sales, telephone solicitations, letters, and direct approach, last year "Kehai" developed more than 1,000 uncompensated consulting activities, which were well received in all circles.

In order to hasten the application of technical achievements, "Kehai" has emphasized training efforts. In 1986, the center held 48 technical training classes of various kind, at which more than 3,100 people received training from more than 2,000 units all over the country. They printed and distributed 250,000 volumes of learning materials, from which were obtained excellent social results.

In 1986, "Kehai" also established and strengthened its operations system in which marketing was the central link, and it founded operational thinking that centers on economic results. A computer company is the economic mainstay of "Kehai," and it has adopted retail sales operations centering on marketing. Technology development uses marketing for support, systems engineering uses marketing, maintenance services engage in marketing, and each type of work takes marketing as its take-off point and point of return, which has quickened the pace of development, improved the service situation, and improved economic results.

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1986 PROGRESS IN S&T SYSTEM RESTRUCTURING REVIEWED

Beijing KEJI RIBAO in Chinese 16 Feb 87 p 3

[Report by the Laboratory for Managing Science, Center for the Promotion and Development of Science and Technology in China: "A Review and Look Ahead at the Restructuring of the Science and Technology System in 1986"]

[Text] Recently, regarding conditions concerning the restructuring of the science and technology system, we did a sampling survey of 379 independent research organizations, 316 enterprises, and 264 enterprise research organizations in the fields of metallurgy, chemical engineering, machinery, light industry and textiles, electronics, and commerce, from which we have done a preliminary analysis.

The restructuring of the science and technology system has not only propelled the work of science and technology toward economic construction, but at the same time has also been beneficial to the growth of the cause of science and technology itself.

Among the 379 independent scientific research organizations surveyed, through the restructuring of the science and technology system 75 percent of these organizations increased the number of scientific research projects they have, 61 percent showed an improvement in the level of scientific research, 47.8 percent experienced an increase in the scale of projects, 57.6 percent had an increase in the degree of project difficulty, 67.9 percent experienced a reduction in the average time available for projects, 50.1 percent expanded their research organization autonomy, 47.9 percent saw an increase in opportunities for staff training, and 82.1 percent underwent an improvement in living standards for their staffs. There was a tendency toward diversification of the sources for scientific research projects, some research organizations continued to focus on vertical tasking, some concentrated on accepting bidding and contract projects, and some mostly engaged in projects commissioned by enterprises. Ninety percent of scientific research organizations transferred the rights to their technology primarily to small to medium-size township enterprises, and 78.2 percent of scientific research organizations have adopted the mode of compensated transfer of rights to technologies. In the process of catering to the economy, there has been a strengthening of real economic power for the scientific research organizations. Statistics show that for the three indices measuring per-capita income for academic or institutional

organizations, per-capita income from the transfer of rights to technologies, and per-capita income from scientific research funding, those statistics for 1986 exceeded those for the 1985 scientific research organizations by 64 percent, 66 percent, and 80 percent, respectively.

The effects of the restructuring of the scientific research organizations from implementing the restructuring of funding have been quite marked. Each index for research organizations is higher now than before implementation of the funding restructuring, and this effect has been all the more remarkable for per-capita research funding, research organization autonomy, staff training opportunities, and the standard of living for staffs. These kinds of research organizations have for the most part formed relatively stable cooperative relations with enterprises, and the transfer of their technological achievements clearly had a transregional, trans-sectoral aspect.

Although the ongoing restructuring of the science and technology system has had a certain effect, it is still insufficient to satisfy current demand for advances in enterprise technology.

The survey of 316 enterprises shows that in 1986 enterprises with a ready market for products fell to 28.4 percent from 48 percent the previous year, and at the same time enterprises with unmarketable products rose to 19.9 percent from the previous 11 percent.

According to another survey taken by the relevant departments of 40,000 major state-run industrial enterprises contained within the national financial budget, within the first 10 months of 1986 output value rose 4.8 percent, total taxes on profits dropped 1.4 percent, losses increased 72.7 percent, and the proportion of enterprises having losses rose from 12.4 percent to 17.1 percent. This tendency for enterprise economic results to drop is well worth watching.

The reasons why economic results dropped are varied, but basically the drop occurred because economic mechanisms in this country are still "quantitative" mechanisms and have not yet become "results" mechanisms. In the production fields, the growth of energy sources and raw-material production has been sluggish; in circulation, products with a ready market are lacking, the tendency for unmarketable products to accumulate is getting worse, production structures are not suited to changes in consumption patterns, and changes in market environments are compelling enterprises to pay even more attention to the adjustment of product structures and to hasten the renewal and replacement of products. Based on the factors just described, 70.8 percent of the enterprises feel that the capacity for technology development associated with their factories has an even more important role for enterprise production operations.

It can be seen from an analysis of the data that among enterprises with factory-affiliated scientific research organizations, 38.2 percent of them have products that are selling well, while 12.1 percent have sluggish product

sales; in contrast, [among enterprises as a whole] 15 percent have products that are selling well and 21.9 percent have ones that are sluggish. This shows clearly that only 2.7 percent of enterprises "have no need for technology development in production operations," but these enterprises are largely local enterprises or are enterprises having products in short supply, as, for example, the metallurgy enterprises.

With the changes in the internal environment and in internal conditions, enterprises must integrate more closely with scientific research institutes. According to statistics from the survey, among current lateral relations between research and production, 59.7 percent of scientific research organizations are still occasionally related to enterprises (mostly, small to medium-size and township enterprises) chiefly based on market needs, 21.6 percent have relatively stable cooperative relations with enterprises, 14.6 percent have joined with enterprises to form research and production association organizations having joint organizational articles of association, and only 1.6 percent have joined with enterprises to form unified operations and unified accounting scientific research/production association organizations, while 77.8 percent of enterprises urgently desire scientific research organizations to incorporate with enterprises.

To strengthen and adjust progressively the organizational structures of research organizations is an objective requirement for the growth of the national economy, and is also an important task for the next step in the restructuring of the science and technology system.

It can be seen from our overall intentions that 85.9 percent of enterprises and 64.8 percent of independent research structures advocate changing the situation regarding the organizational structures of scientific research organizations in China.

The majority of enterprises advocate that technology development type organizations be incorporated into enterprises or into enterprise associations, but believe that enterprises of different kinds have differences when selecting research organizations of various scales. Small to medium-size enterprises mostly select research organizations of 50 persons or fewer, while large-scale enterprises still have a need for research organizations of from 50 to 200 persons or more, even though 92 percent of them have their own technology development organizations.

As far as scientific research organizations are concerned, the majority of research organizations affiliated with ministries of the State Council wish to develop into national industrial technology development and technology service centers or, with pertinent units, to form joint scientific research type companies complete with technology, design, and engineering. Among local scientific research organizations, the majority of those having a greater real strength hope to develop into regional technology development and technology service centers or research type enterprises, with each one catering to small to medium-size enterprises; those having less real strength largely desire to

merge with other research organizations and to strengthen their own development and trial production capacities by joining with enterprises or by absorbing small enterprises.

What is worth noting is that there were 35 independent scientific research organizations (9.4 percent of the total) that have indicated a desire to incorporate with enterprises or with enterprise associations. By analysis, the majority among them are local or municipally affiliated research organizations, most having personnel in the range of 50-100 persons and some which have implemented funding independence. Aside from these, there are two local or municipally affiliated research organizations that have clearly shown they have no conditions for scientific research, and these may be dismissed.

Even though the majority of enterprises hope to merge with scientific research organizations, at the same time the majority of independent scientific research organizations also advocate changing the current status regarding research organizations, but in reality the scientific research organizations wanting to incorporate into enterprises are still a minority. The survey reflects the fact that the primary worries causing independent research organizations to hesitate in taking action are: (1) whether leaders can respect science and technology efforts and the roles of scientists and technicians; (2) whether the autonomy of research organizations will be reduced correspondingly; and (3) whether the various categories of remuneration for scientists and technicians can be improved

The survey of 264 enterprise research organizations has shown that the concerns of the independent scientific research organizations are certainly not uncalled for. Even though enterprise scientific research organizations have played a greater role in enterprise production operations, there are still 23.2 percent indicating a desire to disassociate themselves from enterprises (12 organizations, or 4.5 percent, among them wish to become independent research organizations) and 59.2 percent have responded that their S&T personnel could not be satisfied with their present work. The primary reasons leading to the insufficient stability in enterprise S&T contingents are: (1) the majority of medium-size to large enterprises have not yet been invigorated; (2) enterprise research organizations lack a corresponding autonomy; (3) some enterprise leaderships do not respect science and technology efforts and do not understand S&T laws; and (4) in comparison with independent research organizations, certain policies currently in effect are not advantageous to enterprise research organizations and to scientists and technicians, a view held by some 64.3 percent of the total number of enterprise research organizations.

The existence of these problems causes enterprises to lack the ability not only to attract independent scientific research organizations but even to maintain existing science and technology continents. The majority of those personnel currently leaving enterprises are middle-aged key technicians ranging in age from 35 to 50, and they are leaving for government organizations and independent research organizations. The majority of enterprises

estimate that with freedom of movement for skilled personnel, the number of remaining scientists and technicians will continue to decrease.

The conditions just described lead us to believe that while we encourage independent research organizations to incorporate into enterprises, we must adopt corresponding policies and measures, strengthen the vitality of enterprises, be sure to resolve the real problems and difficulties in the work and lives of enterprise research personnel, and create an excellent environment for the incorporation of independent research organizations into enterprises.

The next step in the restructuring of the science and technology system should be to stress consideration of several problems.

1. The restructuring of the science and technology system is one system in the entire restructuring of the economic system, and without doubt it has been limited by the objective factor that there is a lack of vitality in current enterprises, but the restructuring of the science and technology system is still something that can be done, and it should be interdependent with the restructuring of the economic system and conditional upon it. Just as when invigorating enterprises we cannot expect at once to have a stable buying market and harmonious environment before restructuring, neither can the restructuring of the science and technology system wait for enterprises to be invigorated. Not only must the restructuring of the science and technology system in China suit the new trend of the deepening development of enterprise restructuring, but at the same time we should create the conditions amenable to the deepening growth of the economic system restructuring and the national administration and management systems restructuring.

2. The primary goal in restructuring the science and technology system is to bring about a close integration of existing science and technology capacities in this country with the growth of the national economy, and especially is to strengthen the innovative capacity of industrial technology. The mission that now confronts us is to assist enterprises in quickening the renewal and replacement of products, to improve economic results overall, and to strengthen our capacity to generate foreign exchange through exports, and this is an important standard by which to evaluate the success or failure of the restructuring of the science and technology system.

3. In order to implement the goals just stated, the restructuring of the science and technology system must progress along economic and S&T boundaries, proceed from China's economic, scientific and technical, and social development strategies, and integrate adjustments in commodity structures, and there must be a rational deployment of scientific and technical strengths throughout the country (including enterprise and civilian S&T strengths). We should not just limit this to promoting the catering to economic construction by the "Five Great Front Armies."

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CHINESE ACADEMY OF SCIENCES EMPHASIZES TECHNOLOGY EXPORTS

Beijing RENMIN RIBAO (OVERSEAS EDITION) in Chinese 22 Feb 87 p 4

[Report by Kong Xiaoning [1313 2556 1337]: "Chinese Academy of Sciences Strengthens Technology Exports"]

[Text] Many people abroad have come to realize that the Chinese Academy of Sciences (CAS) is primarily engaged in basic research. Therefore, that some foreign and Hong Kong commercial interests have seen at the Shenzhen CAS Keshen Company that CAS has several good products for foreign sale cannot help eliciting exclamations of wonder.

Some time ago, in the early part of 1980, CAS established the Far East Scientific Instruments Import-export Company, and some institutes also founded similar organizations, all devoted to the dissemination and application of new achievements. Last year, the generation of foreign exchange from technology exports throughout the academy reached more than $6.8 million, and export trade relations have been established with 26 countries and regions.

Rights to the new two-step fermentation production technique for vitamin C invented by the CAS Institute of Microbiology were last year transferred to the world's largest producer of vitamin C, the Swiss (LUOSHI) Company. Fees for this transfer totaled $5.5 million, of which $2.5 million have already been received, making this the largest technology transfer item ever sold abroad by China to date.

Because of a lack of technical capability, one Japanese company that manufactures various transducers, a famous "ceramics corporation," had no way to manufacture infrared optical filter sheets for use with transducers. But the Shanghai Technical Physics Institute had a strong technical base in this area. Both parties agreed to establish the Nisaila Transducer Company, Ltd., to manufacture transducers and optical filter sheets as a joint venture, all products to be sold abroad. By going abroad to run factories jointly, and in using technology exports to stimulate the export of equipment and labor, the CAS Chemistry Institute has broken into the front ranks.

The major achievement of this institute, "polyacrylic cooling MULI [3018-4721]," is being used in more than 60 factories in China, which has allowed polypropylene fiber production in China to vault into the international ranks. On this

basis, this institute is running a joint venture with Thai companies, the "Si-Te (Group) Company, Ltd," and is operating the factory by cooperatively using technology and electromechanical equipment and instruments for shareholding, by which means they can generate equipment exports worth nearly $1 million.

How we are to aim at international markets and strive to export even more technology products have been central problems for the last few days at the CAS International Joint Technology Development Conference. Relevant officials have pointed out at the conference that for CAS, with its more than 40,000 outstanding S&T personnel, a major task in the future will be to use the restructuring as the motive power and to adopt various modes by which to strive to export high-level, high-quality technical products.

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SITUATION REGARDING NON-DESTRUCTIVE TESTING EXPLORED

Beijing ZHONGGUO JIXIE BAO in Chinese 24 Feb 87 p 4

[Report by Chen Jimao [7115 4480 2021], Society for Non-destructive Testing, China Institute of Mechanical Engineering: "The Current Situation in China and Development Goals Regarding Non-destructive Testing"]

[Text] China's machine industry products currently have the problems of a short life, poor reliability, and a high rate of mishaps. Although the reasons for these problems are varied, we should say that it is quite relevant to the backwardness of our non-destructive testing technology.

We may say that non-destructive testing technology in China is only at the level of that of the later 1950's in industrially developed nations.

The policy factors that have been chiefly responsible for obstructing the development of non-destructive testing technology in this country are:

For quite some time now, the products of our machinery industry (and especially the products of the national defense industry) have not been market competitive, pricing policies have not been reasonable, and this has led to "top quality but not a top price" and "extension of life expectancy but not of price." Product quality has been improved, but there has been no economic result therefrom. Consequently, in terms of policy, this has then changed the means of non-destructive testing into obstacles and stumbling blocks that limit the growth of production for enterprises, even to the extent that technology efforts in this area fluctuate wildly, never able to take their rightful position.

For ensuring product quality, and especially for ensuring the quality of major products that seriously affect the security of the national economy and the people's livelihood, we still lack a complete set of decrees, rules, and regulations. After we experience serious quality mishaps, which have been limited to factors involving natural disasters, processing and manufacturing, and the use of equipment, seldom do we then adopt measures to improve the quality and strengthen testing. There has been no formal proposal by the state or any system or department to allocate special funds to undertake non-destructive testing.

The chief mechanical industrial products in China have been marketed as state monopolies, and the supplier has not necessarily considered the needs of the requesting party. Information about products cannot be feed back promptly, so we cannot use this important channel to advance the study, development, and dissemination of non-destructive testing and quality control.

We lack specialist personnel, and the personnel we have lack quality. There is no source for specialist personnel, which makes the clash between this technology-intensive specialty and the level of personnel all the more acute. Add to this the fact that testing work is also considered by others to be secondary to, and more relaxed work than, direct production, and that is why there are so many old, weak, sick, and disabled among testing personnel, as well as those who have been admitted due to connections. This has without doubt brought difficulties to the management, development, and dissemination of non-destructive testing technology.

The production of non-destructive testing equipment has still not constituted a base in China. The state has no overall unified planning for it, and it lacks necessary support and protection and fostering through policies. The technological capacity of the majority of instrument-manufacturing plants is weak, their equipment is obsolete, and they lack the capacity to develop new products. Consequently, the level of the product technology is low, the quality is unstable, the products are dull, and renewal and updating are slow. At critical times, we cannot but seek help through imported instruments.

We have not established corresponding standards. The standards for non-destructive testing are directly related to the applications of new methods, and this is also quite closely related to testing reliability. There is still no standards formulation organization in this country for non-destructive testing, and each industrial system also lacks uniform planning, the result of which for each trade in the industry is a lack of major results from strenuous effort, which makes it even harder to obtain international recognition. This is not advantageous for the strengthening of non-destructive testing, for improvements in product quality, and for international exchange and competition.

In view of the fact that the current basis for non-destructive testing technology and related disciplines in this country is somewhat backward and our economic power is somewhat weak, it would not be very realistic to propose catching up to the levels of industrially developed countries within the near future. However, when it comes to non-destructive testing technology that serves to promote quality, different levels, varieties, and results, we cannot permit there to be a distinct gap in the testability and reliability of the testing technology itself, for otherwise our machinery industry products will find it difficult to enter international markets. Consequently, at present we should emphasize breakthroughts in reliability for testing sensitivity and testing methods themselves. This would require of us that we quickly establish a scientific and technical contingent for powerful non-destructive testing all the way from the institutions of higher learning and the institutes to the manufacturing plants. They would bring to non-destructive technology a uniform testing system, one that would extend from overall testing to microcosmic testing, would develop from qualitative testing to quantitative

evaluation, and would develop from production testing rules to that which includes usage, protective investigation, and dynamic monitoring.

By the end of this century, the strategic goals for non-destructive testing in this country will be:

Universal application of microcomputer technology and advanced data-processing technologies and energetic development of testing technologies for microscopic blemishes and comprehensive strengthening as well as the ability to be practically applied to the assurance of product quality.

Such new technologies and applications as acoustic emissions, lasers, microwaves, and optic fibers will enter the field of non-destructive testing in the areas of production and maintenance, and this will make the most of non-destructive testing technologies regarding economic results.

We will actively develop quantitative non-destructive evaluative technologies, and strive to apply these to key locations on chief products, which will go on to realize a longer product life and reliability for use in effective guarantees.

We will give full play to process monitoring and automatic monitoring technologies. Using automatic monitoring or real-time monitoring technologies in the manufacturing process will fundamentally eliminate rejects and inferior products due to instability in the parameters of manufacturing techniques.

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SHANGHAI EXPORT OF S&T ACHIEVEMENTS NOTED

Beijing RENMIN RIBAO (OVERSEAS EDITION) in Chinese 28 Feb 87 p 1

[Report by Xia Ruge [1115 0320 7041]: "Advanced Technology from Shanghai Welcomed in International Markets"]

[Text] A group of advanced technologies from Shanghai has been welcomed in international markets. An official of the Department of External Economic Relations for this city said that they had been recently and would in the future be offering nearly 300 technologies exclusively for export in trade to international markets.

Recently, some firms from such countries as the United States, Japan, Holland, Austria, Canada, and Italy and from Hong Kong have indicated their intention to buy more than 10 technological achievements.

Over the past few years, the primary forms of technology which Shanghai has exported have been technological products, whole sets of equipment, project packages, cooperative development and certified trade projects and the sending of high-level skilled personnel, among which more than 60 items alone have been export software products. Advanced technology exports have been welcomed by firms in the United States and Japan, as well as in some countries and regions of Europe and Southeast Asia, for example, the arsonium crystals developed by the Shanghai Silicate Institute, the technology for which has reached the front ranks internationally. The distinguished American scholar Professor Ding Zhaozhong [002 5128 0022] has bought a total of several thousand tons of the product. The "CRDB Relational Database Management System" sold to the American "Intelligent Data Company" [ZHINENG XINXI GONGSI] by Shanghai in 1984 has often been praised by users. In recent years, more than 60 technology items have been used by Shanghai to spur on exports.

To expand the shipment of advanced technological achievements to international markets, pertinent departments in Shanghai have decided to export only technology achievements. Some of the nearly 300 technology achievements offered to foreign firms at this time concern the fields of textiles, building materials, industrial chemicals, metallurgical products, machinery, software, electronics, agricultural products, instruments and meters, shipping, services light industry products, and foodstuffs.

One official of the Shanghai Commission on External Economic Trade said that patents have been requested both at home and abroad for the export technology achievements provided by Shanghai. These achievements will be exported through various means such as certified trade, transfer of the rights to technologies, shareholding cooperation, consulting services, and project packages.

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SHENZHEN INDUSTRIAL PARK OPENS TO CIVILIAN ENTERPRISES

Beijing GUANGMING RIBAO in Chinese 9 Mar 87 p 1

[Report by Wu Xiaomin [0702 2556 3046]: "Shenzhen S&T Industrial Park Establishes Civilian S&T Development Fund"]

[Text] In order to hasten the transformation of scientific research achievements to large-volume product production, and to allow research achievements to have free rein to produce social and economic results as quickly as possible, the Shenzhen Special Economic Zone recently established a civilian S&T development fund at the S&T Park.

Deputy Mayor Zhu Yuening [2612 1878 1337] said to reporters that for all projects involving S&T development products led by S&T personnel in China, a civilian S&T enterprise of considerable scale was being established within the "Science and Technology Park" in Shenzhen, and that all could apply to use this "fund" for development projects and for production. S&T development projects such as microelectronics and information engineering, optoelectronics, precision machinery, new materials, new energy sources, biological engineering, fine chemical engineering, and marine engineering all have preference in obtaining access to this "fund."

The management and evaluation of this "fund" are the responsibilities of the "Civilian Science and Technology Development Fund Commission," and the fund commission will do technical demonstrations and economic result appraisals for development projects that apply to the fund. This fund will adopt the method of compensated use in providing for scientists and technicians who comply with the conditions, the longest period for use of the fund will not exceed 5 years, and beginning from the first profit-making year, operating expenses of from 15 to 30 percent will be taken from net profits each year.

In accordance with the particular conditions of development projects by civilian S&T enterprises, the funds provided for S&T personnel of the operating enterprise will be divided into six categories: 10,000, 20,000, 40,000, 60,000, and 100,000 yuan. Based on conditions, S&T personnel must invest from 500 to 1,000 yuan in cash reserves to act as capital for civilian S&T enterprises. If the scale of the enterprises is larger, the amount required for investment will be larger, after which there can be joint operations and joint initiation of operations with the "S&T Park." As, for

example, with the key equipment and materials needed by civilian S&T enterprises to develop products that must then be imported, where for things the total price of which is less than $10,000, the fund commission will provide help to the enterprises in resolving problems with raising money. If the scientists and technicians of the founding civilian S&T enterprise make their best effort but still cannot attain their expected goals, the "fund commission" can assume part of the risk in light of particular circumstances.

Deputy Major Zhu Yuening has pointed out that this "fund" will be around for a long time. Those initiating civilian S&T enterprises within the Shenzhen "S&T Park" will enjoy complete independent operational authority as long as they comply with the various decrees and provisions of the state and of the special economic zone.

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PROGRESS DESCRIBED FOR S&T SYSTEM RESTRUCTURING

Beijing KEYAN GUANLI [SCIENCE RESEARCH MANAGEMENT] in Chinese No 2, Apr 87 pp 1-5

[Article by Qing Zhichun [1987 1807 4783], Chinese Academy of Sciences, Shanghai Branch: "Restructuring in Practice"]

[Text] The goal of restructuring the science and technology system lies in urging the better linking of scientific research activities with the growth of society, the economy, and technology. Efforts at technology development that are a direct extension of scientific research activities should be sufficiently respected and fully evaluated. Efforts at technology development by the scientific academies and institutes should stress the technological aspects and should emphasize the shift of new production technologies and techniques into society. We should not confuse the statement "science and technology must cater to economic construction" with efforts by scientific research units to pursue their own economic gains. There is much to do in technology development, there are many modes by which to do it, and its growth depends upon cooperative actions among all aspects of society. Technology development, and especially cooperative development with enterprises, requires the coordination and support of all national social policies. This paper begins from the assumptions just described and presents the restructuring experiences of the Shanghai Branch Academy of the Chinese Academy of Science (CAS).

To carry out victoriously the task of building our socialist modernization, the party and government have proposed the strategic principle whereby "economic construction must rely upon science and technology, and science and technology must cater to economic construction." Proceeding from this strategic principle, we are currently implementing the practice of restructuring in an orderly manner and after a great deal of thought. Our foremost hope is that the restructuring will allow all our research activities to change from the "institute type" to the "operations type" and allow all scientific research efforts to extend out from the closed cycle where disciplines go on continually to a better linking with the growth of society, the economy, and technology. Science is the pursuit of knowledge, and the scope of that probing is unusually broad. To integrate with China's current national situation, we will place greater emphasis on pursuing broad knowledge for resolving major social and economic problems, which will strengthen our capacity for promoting progress in society. We are in the process of adopting measures and creating the conditions that will allow even more scientists and technicians to enter "the field of greater science" from "the field of lesser science." This will allow for the expansion of their own scope of research practice from the relatively

narrow topical research to the greater scope of operations that is coordinated with the overall growth planning of society and the demands of the "four modernizations." And this will also allow for the focus of topic selection to change from one that primarily displays abilities and discovers levels to one that resolves specific problems in social and economic growth. We encourage scientists and technicians to be bold in innovation, to open up new fields of research, and not to stay in some corner and be conservative. We have appropriately stressed the significance of development efforts in order to provide sufficient evaluation and respect for development efforts in a timely fashion. Our understanding of development efforts is that development is the process by which research achievements are made into products or commercialized, that is say, development is the making of new products and techniques on the basis of new knowledge and information provided by scientific research achievements, through further experimental research activities; or it is a major improvement or innovation on an existing product or technique based on newly acquired knowledge and experience. In summary, we are currently exerting efforts to ensure that research is more directly aimed at the needs of social and economic growth, that it serves the rise of new industries, that it serves the technological transformation and technological progress of industrial and agricultural production, and that it contributes to the "quadrupling." At present, we are involved in certain efforts in this regard.

I. Building an Intermediate Testing Base, and Shifting Scientific Research Achievements into Production

With the support and cooperation of Shanghai Municipality, the Chinese Academy of Sciences is building four intermediate testing bases in Shanghai. They are: the Shanghai Bioengineering Intermediate Experimental Base, the Chemical New Materials Intermediate Testing Base, the LSI Research and Development Base, and the Vegetable Foodstuffs Intermediate Testing Base for Irradiated Preservation. The situations regarding these four intermediate testing bases may be briefly presented as follows:

Bioengineering is the focus of world attention, which has seen its rise as an important indication of the "new technological revolution." In the Shanghai region, the Chinese Academy of Sciences already has 7 bioengineering institutes, employing more than 1,600 scientists and technicians. These institutes have combined their various features to develop many studies in various aspects of bioengineering. They have a very good basis in the fields of molecular biology, molecular genetics, cytology, and microbiology, and they have a definite level in the technological aspects of analysis of protein structures, nucleic acid synthesis, gene cloning and expression, cell cultivation, and cytomixis. Based on long-term accumulated efforts and training, in recent years new advances in technology have gained one after the other. For example, the DNA single-strand bidirectional measurement method as proposed and accomplished by Dr Hong Guofan [3163 0948 5672] of the CAS Shanghai Biochemistry Institute, the systematic measurement method for the DNA sequence (non-random measurement method), and the breakthrough in rapid measurement of single nucleotides in DNA double-stranded molecules; the research group led by Professor Li Zaiping [2621 6528 1627] of this

institute, since its successful expression of the Type B hepatitis virus surface antigen gene in yeast, has also successfully constructed a recombinant cowpox virus containing the Type B hepatitis surface antigen gene; Dr Guo Lihe [6753 4409 0735] of the CAS Shanghai Cell Biology Institute, using as a carrier the multi-function plasmid he developed himself, has had success in efficiently expressing human insulin in intestinal baccilli; and Dr Xie Hong [6200 1738] of this institute and his research group have used the technology for hybridizing tumors to synthesize liver cancer monoclonal antibodies, under the direction of Professors Yao Xin [1202 9515] and Chen Ruiming [7115 3843 6900]. The Yang Shengli [2799 0524 0448] and Wu Ruping [0702 3067 1627] research group of the CAS Shanghai Pharmacology Institute has also had good results in the field of penicillin acylatase (xianhuamei 7913 0553 5326] genetic engineering research. Based on a great deal of research accumulating over several years and on the maturing of skilled personnel, to which are added the conditions of having other material technologies, the state has approved of CAS' constructing bioengineering intermediate testing bases in Shanghai. With the great support of various quarters in Shanghai Municipality, construction work is progressing smoothly. At the same time as capital construction is underway, pre-development research is being done by relevant institutes on a group of projects intended for development, among which are included projects in genetic engineering and cellular engineering, as well as projects in microbioengineering and enzyme engineering. After completion of capital construction, these things will make contributions to technological progress in the industrial sectors of Shanghai's foodstuff and pharmaceutical industries, as well as to chemical engineering and light industry, or they will promote the formation of new industrial sectors. The bases will be of an open type, and relevant units or individuals can do cooperative research and development or intermediate testing as guests at the base. It is our hope that with the growth of this undertaking a real step can be taken in the promotion of the industrialization of biological technologies in this country.

2. Intermediate Testing Base for New Chemical Materials

New materials are invariably the material bases for the new technologies and new products of an age. In consideration of the extreme importance of new materials regarding the development of new technologies and rising new industries, CAS is primarily relying upon Shanghai's Organic Chemistry Institute and the Silicate Institute, as well as on factories affiliated with those two institutes, to build the intermediate testing base for new chemical materials. This base will develop new materials from organic chemistry, as for example, element organic functional materials, precision organic industrial chemical products, new special polymer materials, etc.; also, it will develop new inorganic materials, as for example, engineering ceramic materials (especially high-temperature structured ceramic materials), functional ceramic materials, artificial crystalline materials, and superhard materials as well as functional optic fibers and functional thin-film materials. There will be an open style of management after construction of the bases, which will provide opportunities and conditions for development and experimentation in transforming the laboratory research achievements from all the nation's interrelated research units. At the same time, the bases will also provide in small quantity products made of special materials for both domestic and foreign markets. Completion of the

bases, aside from providing new materials for the renewal and updating of traditional products, can also promote the growth of high technology in China and the establishment of new industries, bringing direct or indirect social and economic results.

3. LSI Research and Development Base

Among contemporary technologies, LSI has an important function. We in China must exert tremendous efforts in this regard before we will be able to meet the demands of domestic technological development. In order to improve their capacities for absorption and assimilation and for development and innovation, and to promote the improvement of the level of production for LSI in this country, CAS and Shanghai Municipality are jointly funding, on the basis of the microelectronics division of the CAS Shanghai Metallurgy Institute, the establishment of the Shanghai LSI Research and Development Center research base. After construction of the base, the center will initiate planned research in accordance with Shanghai Municipality's developmental planning, consequently contributing to new LSI products in Shanghai Municipality. To allow developmental efforts to be established on an even higher initial level, we are in the process of pursuing opportunities and appropriate means of cooperative development with similar foreign interests. Base construction is currently progressing at a hectic pace.

4. Intermediate Testing Base for Vegetable Foodstuff Irradiated Preservation

Regarding nuclear technology serving the national economy, the CAS Shanghai Atomic Nucleus Research Institute has been undertaking explorations in several areas. It is understood that in general about 20 percent of the 1.25 million tons of vegetables produced annually in Shanghai is naturally lost in shipping and storage. The shipping and preservation of all kinds of fruit have similar problems. With this in mind, the Shanghai Atomic Nucleus Research Institute and the Shanghai Municipal Vegetable Company are jointly proposing the establishment of an irradiated-preservation intermediate testing base for vegetable food products. This suggestion has been approved and is supported by CAS and the Shanghai science and technology commission, which have resolved that both parties can jointly build an irradiation installation on a scale suitable for intermediate testing and production. The first phase of the project has been completed. In the process of building this, they have begun to use the technological situation at the Shanghai Atomic Nucleus Research Institute, and with the cooperation of more than 10 pertinent units, studies are being done on 25 topics concerned with irradiated storage and preservation, as for example the optimum irradiation techniques for various vegetable and fruit food products, new packaging technologies, the nutritional component of irradiated vegetables, and toxicity analyses, all of which have yielded affirmative results. This ensures that the base will go into operation on time, and that it will serve as a model.

"The Asia and Pacific Region Academic Conference on Actual Applications for Food Product Irradiated Preservation" was held in Shanghai from 7-11 April 1986. Scholars and experts attending the conference, among whom was Professor M. Zifferero, deputy general secretary of the International

Atomic Energy Organization, enthusiastically evaluated the base facilities and working plans, and they believe that there is already a commercial significance for the base.

T building of the four bases just described is based upon the results of years of accumulated research efforts at the various CAS Shanghai institutes. At the same time, it is also based upon environmental conditions in Shanghai. These bases will constitute intermediate testing stations in the transition of research achievements into agricultural and industrial production, will constitute experimental models for initiating new industrial sectors, and at the same time will serve to foster and train skilled personnel.

II. Develop Lateral Relations, Integrate with Production Through Various Channels and Modes, and Serve Production

What we mean by lateral relations is that with the guidance of national policies and to resolve certain social and economic problems, pertinent institutes, institutions of higher learning, and production units will establish coordinated or cooperative relations through various contractual means or different types of association and organization to accomplish the scientific and technical tasks that have been decided upon. The significance here is that the conditions of various parties can be used and coordinated to make the most of advantages and to supplement shortcomings, to reduce the periods of time necessary for research and test production, and to aid in the rapid transformation of scientific research achievements into appropriate technologies or products. In practice we have adopted many different modes, some examples of which are the following:

1. Establishment of Relations Between "Foundations for Development of Shanghai Industrial Technology" and Shanghai Industrial and Economic Circles, As Well As Assumption of Responsibility for New Product Development.

As jointly proposed by the responsible economic, scientific and technical, educational, planning, and financial departments of Shanghai Municipality and a group of institutes and a group of higher institutions from CAS in Shanghai, as well as units of the Shanghai Municipality Academy of Social Sciences, "foundations for the development of Shanghai industrial technology" have been established with the approval of the Shanghai municipal government. A "foundation" is a consultative, coordinating organization that has reserves of funds allocated by financial departments and also has the vigorous support of banking credit. The mission of the "foundations" lies in utilizing economic levers to promote the transformation of scientific and technical achievements into products, the importation, absorption, and assimilation of advanced foreign technology, the promotion of the growth of rising new industries, and the improvement of the degree of nationalization for major products. They provide information and funding support for projects that have authorized consultation and that can achieve optimal investment results or for applicant projects that have been chosen. Based on the social and economic significance of the selected projects, financial support will be done through various means, as for example where there are provided uncompensated subsidies, risk investments, general investments, or preferential loans at

different interest rates. Some institutes of CAS in Shanghai have enthusiastically participated in "foundation" activities and, with the support and financial assistance of the "foundations," have worked actively to develop the nationalization of industrial-use laser-processing equipment, and to develop photoelectric converters and certain special instruments and materials. The principles and directions maintained by the "foundations" have been praised and supported by all parties, and the scale of their activities is progressively expanding.

2. Establishment of Associated Technical Service Centers to Resolve Production Technology Problems with Industrial Sector

Based upon research accomplishments in the areas of metallic corrosion and protection, the CAS Shanghai Metallurgy Institute has sponsored the establishment of the "Shanghai Metallic Corrosion and Protection Technology Center." This proposal has brought a widespread response and has received vigorous support from the Shanghai Municipality science and technology commission. The "Center" has united the combined technological capacity of 9 research and design units, 2 institutions of higher learning, and 13 factory enterprises, a total of 24 units, to form a lateral association oriented toward the entire country that joins anti-corrosion engineering research, design, production, and implementation. It has been ruled to be a non-profit technology service enterprise, the mission of which is to take on major research and engineering projects, to develop technological consulting, to disseminate scientific and technical achievements, and to improve the technological and economic results for industrial enterprises. Due to its rather effective activities, not long ago yet another group of units applied to join the "Center." Units that are a part of the "Center" are given preference in using the technological reports and information at the "Center," receive technological support from one another, and are given preference in receiving the tasks passed on through the "Center."

3. Signing of Technology Cooperation Agreements, and Wide Ranging Service to Society

In implementing the principle that "science and technology must cater to economic construction," the signing of technology cooperation agreements and the acceptance of responsibility for social duties have become important means through which institutes provide assistance to society and make contributions to it. In 1985, various institutes at CAS Shanghai signed more than 640 contracts of various kinds with pertinent units. Looked at from the point of view of the contracted duties that have been entered into, 27.8 percent are for the promotion of scientific and technical achievements in the form of transfers of rights to technologies; 10.5 percent are for providing products; 7.3 percent are for forming associations to develop products jointly; and 54.4 percent are contracts for consulting services. If these are classified according to the parties with whom the agreements have been signed, 1.4 percent are large-scale enterprises; 39 percent are small to medium-size enterprises; 25.6 percent are township enterprises; 20.9 percent are research units; 8.1 percent are institutions of higher learning; 0.8 percent are foreign industrial or commercial interests; and 4.2 percent are based on provisional contracts. The regional distribution of these other parties is: 41 percent in Shanghai; 15 percent in Jiangsu Province; 9.4 percent in Beijing; 7.7

percent in Zhejiang; and the remaining 27 percent distributed throughout China. For the institutes to accomplish these contracts will mean contributions to the growth of production or of society. Lateral relations of this sort will continue to expand and will grow in the direction of integration with large-scale major enterprises.

III. Development of Association with Pertinent Foreign Units Through Various Means, based on Autonomous Research

China's open door policies have created the conditions whereby we can undertake wideranging international exchanges and cooperation. They have also provided opportunities for appropriate professions abroad to understand the wisdom and intelligence of Chinese scientists and technicians as well as their creative capacities. In recent years, on the basis of autonomous research, many of our institutes have sought out possible modes for joint development with foreign units. Our thinking is that through the joint development of mutual cooperation, it is possible to realize higher starting points, higher speed, and great results for developmental efforts. For example, the anti-tumor compound AT-2153 cooperatively developed by the CAS Shanghai Pharmacology Institute and the Japanese Zenyaku Kabushiki Kaisha, and the aerial remote-sensing fine-spectrum infrared scanner developed jointly by the CAS Shanghai Technical Physics Institute with the American Global Environmental Research Company (GER), have provided positive results in these areas. Presently, the Shanghai Technical Physics Institute is engaged in substantive negotiations with a Japanese company for the cooperative development of certain transducers. We hope that this cooperation will also lead to excellent results.

In the process of carrying out this work, we have quite consciously recognized throughout that institutes of the academy must see scientific and technical development as extensions of research activities. Scientific and technical development is not the copying and production of traditional products, and therefore, if we are to do a good job with development, we must rely upon existing technology accumulations and training, where our background is the technological conditions at the institutes. At the same time, we also realize the solemn nature of principles and policies that "science and technology must cater to economic construction," "promote the commercialization of technology achievements and open up the technology markets," and "do business with technology commodities" is totally unrelated to the common aphorisms like "earn money and make profits, be economically self-sufficient," "in order to generate income, do a wideranging business," and "pay for imports and sell them again, which both increases income and generates foreign exchange." We must not confuse the issue of "catering to economic construction" with that of seeking unit self-sufficiency in the area of economic income. Only in this way can we integrate the research planning of the institutes to form a correct purpose of development and to formulate reasonable development planning, which will allow for the healthy growth of development.

In addition to this, we have paid attention in our technology development efforts to the administrative levels of technology development in order to pursue the greatest social and economic results from development efforts.

CAS institutes in the Shanghai area have incorporated general "scientific and technical consulting," "technical services," "technical courses and training," "non-standard product processing," and "the provision of special products" among their regular scope of operations and have placed the emphasis of their efforts on shifting new production capacities into societies, on establishing rising new industries, and on developing new techniques and new products. Some institutes have gone even further to join together their development efforts with models for future growth. They have also placed the brunt of their energies into such major items as establishing lateral relations, organizing associated development entities, and jointly taking responsibility for contracted tasking with industrial enterprises and with departments responsible for work. These units all understand that only with an eye toward high technology can we force ourselves to shift our scale of comparison toward advanced international standards, consequently improving our capacity for actual combat in high-technology development. By enabling ourselves to compete in international markets we will be doing all that we can do to improve the levels of our technology. There need be no doubt that institutes of CAS will always do their utmost to allow their own primary work to "go a little further, look a little further ahead, and become a little more intense." They will "know how things are and how they got that way," and will consequently provide ever newer scientific guidance in the maintenance of growth of production, and in strengthening capacities for independent innovation and future progress.

Naturally, not all things are satisfactory. First of all, the budgeted investment capacity needed for development efforts is very weak. At present, because the vitality of medium to large-scale enterprises has not been fully realized, they lack the real economic power to purchase technological achievements, to which is added the fact that banking credit has yet to take S&T development seriously and that a tradition of scientists and technicians using credit has not yet formed, and this has resulted in a striking lack of economic means for joint development. What many enterprises need is to bring in technological achievements immediately, the economic results of which are readily practical. Second, the conditions and capacities with which CAS institutes provide complementary engineering industrial technologies to enterprises is limited, and the research capabilities for many of the enterprises are also weak, which then creates difficulties in the transformation of scientific and technical achievements into products or commodities, and which increases the difficulty in organizing and coordinating. Furthermore, there are still some low efficiency procedures in management systems, and national tax revenue policies are imperfect, which frequently causes some work to encounter additional obstacles. All of these things have led us to understand that there are still some problems in the actual practice of restructuring that are in need of tenacious resolution. Our responsibility is to maintain unceasingly the advance of the restructuring, allowing it to develop further in breadth and depth.

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ELECTRONIC SYSTEMS ENGINEERING PROFESSIONAL SOCIETY FOUNDED

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 15, No 1, Jan 87 p 9

[Article: "Electronic Systems Engineering Professional Society of the Chinese Electronics Society Formally Established"]

[Text] Organizing in an optimum way a wide variety of electronic products into a practical engineering system which can undertake and carry out the acquisition, collection, transmission, storage, exchange, and utilization of certain kinds of information and can resist all types of interference is an important mission facing China's modernized economic and national defense construction. The electronic information profession and its practitioners will be its main force.

This form of engineering not only involves the development of many resources and relies on the support of information theory, cybernetics, operations theory, systems science, thought science, and computer science, but it also requires close coordination with all relevant departments. In order to promote the development of this new, highly comprehensive science both horizontally and vertically and to exploit the merits of horizontal contacts of science and technology workers and economic workers, in recent years the Chinese Electronics Society has been deliberating and organizing a scholarly organization suited to these demands.

In his scholarly address at the Chinese Electronic Society's Electronics Systems Engineering Professional Society founding meeting and scholarly discussion meeting, Shen Zhongyi [3747 0112 5030], deputy chairman of the Science and Technology Committee of the Ministry of Electronics Industry and the society's adviser, raised a series of very inspiring and significant views with regard to such issues as how to use the methods of systems engineering to organize electronic information engineering systems, how to deal correctly with the relationship of self-design and technological imports, and how to coordinate relevant departments participating in a specific project. When citing the lessons of experience in China and abroad in carrying out relevant engineering projects, he emphasized that the optimum policymaking of the organizers of a large project with regard to the system should be based on through proof of the overall scheme and the use demands and should establish a quality control system and an effective feedback system for the constant

improvement of overall design. He also emphasized that in organization and implementation, from the beginning one should start by formulating and promoting standardization, serialization, and modularity to create the conditions for technological imports to achieve the mission of self-reliance and the nationalization of products in the future.

Senior Engineer Feng Shizhang [7458 0013 4545], who chaired the meeting and is chairman of the Professional Society, announced that the initial committee would be made up of 41 specialists. Comrade Huang Ping [7806 5493], who is the society's adviser, gave an important speech at the meeting. Forty-one papers were read at the meeting, reflecting research results in electronic systems engineering in China in recent years.

China has a vast territory which it is relying on electronic systems engineering specialists to cover, and the Electronic Systems Engineering Society has heavy responsibilities.

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FORUM ON INFORMATION THEORY HELD

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 15, No 1, Jan 87 p 35

[Article by Wu Weiling [0702 0251 7117]: "Forum on New Directions in Information Theory Held in Guangzhou"]

[Excerpts] on the eve of the 30th anniversary of the founding of the Guangzhou Electronics Society, the China Electronics Society's Information Theory Specialization Society convened a "Forum on New Directions in Information Theory" on 19-22 November at the South China Engineering Institute.

The features of this meeting were new directions, new contents and an intense academic atmosphere. Among the 51 representatives were 30 professors and assistant professors and 11 Ph.D. and M.A. graduate students. The papers read at the meeting included those on the latest trends in information theory developments abroad and on the latest results of domestic research. In terms of content, not only were there traditional classical Shannon information and encryption theory but also bioinformation, which has a strong practical background, and topics in such areas as processing, cryptology, etc.

Another characteristic of this conference was that there were both scholarly reports and scholarly discussions. Two special discussions were arranged for the meeting: one was a special discussion on what direction China's information theory should take, and in addition to conducting more in-depth research on classical Shannon information theory, those attending the meeting felt that it is necessary to seek out new topics in practice, to break through the narrow Shannon conventions, to open up the research scope of information theory to make contributions to the four modernizations. On the other hand we should pay careful attention to and follow closely the direction of the latest developments in information theory abroad. The second special topic organized for the meeting concerned conscientiously planning the 1988 Beijing International Information Theory Forum.

The representatives at the meeting felt that in order to move towards the world in the information area it is necessary to begin to make preparations now, to have planned organization and well-grounded manuscripts, and they proposed selecting at next year's national annual information theory meeting a group of first-rate papers for inclusion.

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THIRD NATIONAL OPTICAL FIBER COMMUNICATIONS SYMPOSIUM

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 15, No 1, Jan 87 p 89

[Article: "Third National Symposium on Optical Fiber Communications Held in Guilin"]

[Text] The Third National Symposium on Optical Fiber Communications held jointly by the China Electronics Society's Communications Society and the China Communications Society's Optical Communications Specialization Committee was convened at the Ministry of the Electronic Industry's 34th Research Institute in Guilin on 11-14 November 1976 [as published].

The symposium received over 500 papers, and after examination, 251 were approved for inclusion in the volume of papers. The symposium was divided into seven groups for scholarly papers and discussion: basic theory, digital optical fiber transmission, analog optical fiber communications systems and networks, semiconductor lasers and detectors, passive devices, sensors and measurements, optical fiber cable, and measurements and applications.

The scale of this symposium was large, with nearly 400 persons attending. They came from government agencies, institutions of higher learning, user units, plants, and China's institutes engaged in special research on optical communications. That so many papers were provided for this symposium indicates that China has reached a new level in optical fiber communication research and the production of devices. As concerns the research topics, it has expanded from multiple short-wave to multiple dual-window and single systems, the highest speed of digital transmission equipment tests has reached 400 Mb/s, digital optical terminals and interrupters of groups below 140 Mb/s have already opened a system of transmission distances of up to 30 km. By 1975 China had installed 32 digital optical fiber systems, and systems used have gone from primarily shortwave lengths to long-and short-wave lenths. In short we have the capability for the equipment necessary for medium-capacity, medium distance digital optical fiber communcations systems to supply to the users.

At the symposium, Tang Bingwu [3282 0014 0582], deputy director of the Electronic Development Leadership Team Office of the State Council and director of the New Technology Bureau of the State Science and Technology Commission, invited some of the specialists and professors to convene a forum on the issue of the future development of China's optical fiber communications.

FIRST CHINESE INTERNATIONAL RADAR CONFERENCE

Beijing DIANZI XUEBAO [ACTA ELECTRONIC SINICA] in Chinese Vol 15, No 1, Jan 87 p 104

[Article: "Sucessful First Chinese International Radar Conference"]

[Text] The China Electronics Society hosted the first Chinese International Radar Conference in Nanjing from 4-7 November 1986. The conference, which centered on making radar more capable and more intelligent, exchanged over 140 papers and achieved the anticipated results. This was a successful conference. The main results are: the participants understood that China has made great advances in radar engineering and has caught up with the constantly advacing international pace in terms of new technological developments and theoretical explorations; China's specialists have closed the current knowledge gaps and improved their understanding of current development trends; and scholarly friendships among Chinese and foreign scholars were advanced.

Concerning China's advances in radar tehcnology, the following indicate that China is in the front rank in the world in radar development and scale of application: the scholarly talk by Feng Shizhang [7458 0013 4545], the conference secretary and Chinese radar engineering specialist, concerning the more than 100 types of radar systems which China has developed and which are widely used in such areas as national defense, aeronautical navigation, marine navigation, space research, weather forecasting, and earth resources remote sensing and the use of phased-array radar to forecast accurately the landing area of Soviet nuclear-powered satellites; and the various types of radar of the level of the 1970's introduced by such specialists as Wang Yue [3769 2887], Pan Puhua [3382 6225 5478], Wu Shaohu [0702 1421 5706], Kuang Yongsheng [0562 3057 0524], Wang Songshan [3769 2646 1472], Wang Jun [3769 6511], and Zhang Chengbo [1728 3397 3134]; and 702 fire control radar, three coordinate [xiangsao sanzuobiao] radar dynamic [jidong] measurement radar, multiple-wave three-coordinate radar, limited phase scan radar, backward scaterring over-the-horizon radar, and airborne synthetic aperture radar. After the NEW CHINA NEWS AGENCY learned this news it immediately broadcast it widely in China and abroad in both Chinese and English.

Also indicating that China has strength and stamina in following international advanced technology and further promoting radar engineering were the many research projects of the mid-to late seventies and early eighties introduced

in the related papers of such specialists as Xiong Jigun [3574 4949 5981], Peng Yingning [1756 2019 1337], Liang Xunnong [2733 2484 6593], Xie Chunwei [6200 2504 5633], and Huang Weizhuo [7806 3634 0213]; the C wave-band dome phased-array radar which can carry out a 360°, 70°-pitch scan; kesuocheng [0668 4799 4453] MID made up of the 64-step FIR, FFT filter with signal-to-noise ration improvement factor near 48dB; an open-loop digital sidelobe offset system with an offset ratio of up to 18dB and self-adapting jump time of 5-10μs; a bit slice digital-signal processor which in 40 μs can carry out 32-bit composite signal FFT operation and carry out Doppler beam sharpened imaging processing in real time; a digitally controlled target receiver with a dynamic range better than 90dB; various solid-state microwave modules which can be used for solid-state radar; the work of Professor Ke Youan [2688 2589 1344] and others concerning the profound outline of the rather fascinating target classification and recognition radar polarization theory; and papers on radar signal detection and digital signal processing. Their contributions gained varying degrees of approv from foreign specialists and elicited questions.

Specialists from the United States and England presented introductions to phased-array radar, early warning radar, multiple-target measurement and tracking radar, ASR-9 airfield-monitoring radar, low-altitude naval defense radar, and undergroung probe radar, and they filled in gaps in our specialists' knowledge about foreign advanced levels. The new views presented in such papers by specialists from such countries as Norway and Italy as "Adaptive Matching Illumination Radar Summary," "Using Fixed Harmonics for the Design of Target Recognition Incidence Signals," and "A Mature Technology of Radar Data Processing" earned the praise of colleagues at the meeting. Some of China's scholars with regard to the discussion by several Chinese and foreign specialists concerning radar polarization materials development and applications felt that this theory and technology, which began in the early fifties but has only been regarded as having vague prospects, further indicated that it was about to obtain new vital prospects.

There was a lecture by Professor Hill of the United States who has several times been chairman of the International Radar Society, concerning the potential of feedback control with regard to improving radar adaptation to environmental changes and "lock on" to a target, and [regarding the fact that] after radar becomes more intelligent and its functions become more complete, it will pose ever more challenging demands on the main control computer and the persons controlling it. [His speech], and the thesis of Professor Carpentier of France, that the only avenue for radar is to use phased-array control technology, stimulated those attending the meeting to ponder development trends in radar technology.

Through conversations with foreign specialists outside the conference, China's specialists noted the strong interest of the U.S. radar circles in developing multi-base radar, imaging radar, and phased-array radar and in developing radar working frequencies in both the higher and the lower directions.

Professor Suzuki from Japan's Electronic Communications University, who will be the chair of the Second Japanese International Radar Conference (to be held in 1989) hopes that this society's Radar Specialization Society can become a cooperating

organization of this international conference. He also expressed the wish that through cooperation their underground probe radar can be used in experiments surveying China's buried historical relics. Professor Hill indicated that the IEEE's publication will report on the grand occasion of this conference.

Sheng Zhongyi [3947 0112 5030], vice chairman of the Ministry of Electronics' Science and Technology Committee, presided at this session of the conference. Participating in the conference were 47 scholars from such countries as Canada, France, India, Italy, Japan, Kuwait, Norway, Poland, England, the United States, Sweden, and the Soviet Union; among the over 200 representatives from various fields in China who attended were such famous specialists as Zhang Zhizhong [1728 4160 0022]. Zhang Xixiong [1728 6932 3574], Li Nengjing [6786 5174 2417] Mao Yuhai [5403 0060 3189], Sun Zhongkang [1327 0112 1660], and Zhang Zhiying [1728 1807 5391].

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BEIJING AVIATION INSTITUTE BUSY WITH RESEARCH ACTIVITIES

Beijing GUANGMING RIBAO in Chinese 23 Feb 87 p 2

[Report by Yang Zhihan [2799 2535 5060]: "Sudden Increase in Growth of Research at Beijing Aviation Institute"]

[Text] Researchers at the Beijing Institute of Aeronautics and Astronautics (BIAA) have implemented open-door and invigoration policies, which have given a lively new aspect to life there. Comparing 1986 with 1985, research funding grew by 47 percent, and among the 65 achievements appraised last year, 2 were of a national level and 15 were of a ministerial level.

BIAA is a major institute directly affiliated with the Ministry of Aeronautics, and in the past its research has served that system. In recent years, it has restructured the closed research systems under departmental ownership, and with the goal of first completing research tasks assigned by the Ministry of Aeronautics, it has opened up to pertinent ministry commissions and to society. As of now, it has taken on responsibility for 25 research projects from departments of the Ministry of Electronics, the former Ministry of Machine Building, and the China State Shipbuilding Corporation and has also opened six major laboratories, like the Vehicle Air Conditioning and Heating Environment Laboratory, to the public.

In order to transform research achievements into production forces, BIAA has joined together with 16 provinces, municipalities, and prefectures to establish economic and technological cooperation relations or research and production associations, which have taken on 274 research projects. Research expenses for these projects last year were 2.83 million yuan, an increase of 20 percent over the previous year. The first set of motor vehicle air conditioning equipment produced in China, which was developed by BIAA with the Wuhan Motor Vehicle Air Conditioning Plant, has been evaluated and put into production; the Artificial Gem Plant jointly built with Jingde Township is now in operation; and an association formed together with the Beijing Municipal Television Equipment Institute has developed four-stage lighting products that are computer-controlled, for a total output value of 1 million yuan.

BIAA has also cooperated with some foreign research organizations in undertaking research. The fourth-generation mathematical system researched cooperatively with New Zealand, the re-erase/rewrite optical disk researched

with the United States, and the image-processing training center founded jointly with Canada are all progressing satisfactorily and will be of use in importing technology and improving the levels of research.

BIAA research is progressing along three levels. One is aimed at the advanced positions of world S&T development or at major problem-solving projects in this country, the second is application and development research, and the third deals with the "short, even, and quick" projects oriented toward the small to medium-size enterprises and township enterprises. Through these three levels the research strengths of all levels are organized, from the professors and assistant professors to the graduate students and upperclassmen majoring in a particular discipline. In this way they can both improve the scholastic level of the teachers and enhance the abilities of the students in creatively using knowledge and researching problems.

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NEW INSTITUTE FORMED FOR SPACE TECHNOLOGY RESEARCH

Beijing KEJI RIBAO in Chinese 26 Feb 87 p 2

[Report by Chen Guang [7115 0342]: "Primary Base for Space Technology Research"]

[Text] The Beijing Institute of Satellite Information Engineering (BISIE) is a comprehensive research organization affiliated with the China Academy of Space Technology and is primarily engaged in high-level technology research such as the design and development of satellite ground station systems and satellite data reception, processing, and computer applications. It occupies an extremely important position in China's research and development of satellite data and its applications in building up various fields of the national economy.

The other day I visited this institute. The institute director, Tong Kai [4547 6963], and the deputy director, Xu Fangwen [1776 5364 2429], briefed me on conditions at the institute.

This institute was founded in August 1986 from the former Beijing Institute of Radio-controlled Measurement, the Beijing Institute of Remote-sensing Technology, and the Beijing Space Computer Center. Over the past several years, these organizations have done a great deal of measurement control, image processing, engineering calculations, and data processing on behalf of the design of the various experimental satellites from China, and have made contributions to improving the level of satellite design and promoting the growth of satellite development. Since 1978, 1 special prize and 1 first prize for national science and technology advancement have been received here for this work, as well as more than 10 State Science Association Prizes and prizes for scientific research achievements. Well, then, what is the purpose in establishing the BISIE? Director Tong Kai said: "In one sentence, that would be to allow satellite space technology to move from the experimental stage to the practical stage, and to allow for even greater results in the modernization of the national economy."

Director Tong Kai and Deputy Director Xu Fangwen explained that in the past, under the influence of extreme leftist ideological trends, to some degree we saw space satellite technology research as simply the "placing of political satellites." But today, the cause of the four modernizations has made new

demands on China's research into and development of satellite information application technology, namely, for such high-technology means as satellite sensitivity, satellite communications, and satellite navigation and positioning as well as computer measurement control and data management, all of which have brought enormous economic and social results to all departments and industries. The fields are vast and the prospects are broad. For example, by using satellite television reception stations we were able to form an all-China television broadcasting network; by using television relays as the means, we were able to implement all-China and even worldwide computer data communications and telephone circuit communications; and our satellite navigation and positioning techniques can get a fix on moving targets in any position around the globe. In addition, photographic information can be used to do environmental monitoring as well as mineral exploration, territorial surveying, etc. Applications of these technologies can reap enormous social and economic results.

At present, this institute not only has technically advanced satellite ground station systems and satellite remote-sensing data reception and processing equipment, satellite-monitoring and tracking groundstation experimental bases with excellent sites and complete facilities, and computing centers with accurate equipment and advanced technology, but also has a technology contingent that has been tempered through actual practice and testing, that has a high level of technology, and that has had abundant experience. It is currently using these advantages to undertake the reception and image processing of resource satellite information, geosynchronous weather satellite cloud mapping and reception management, and research into the navigation and shifting of satellites and research into satellite space stations. At the same time, it is perfecting satellite remote-sensing information-processing systems and expanded computer scales and computational capabilities.

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